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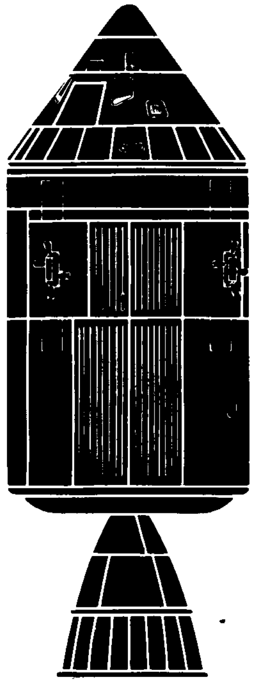

Final Report

PRELIMINARY DEFINITION PHASE
APOLLO EXTENSION SYSTEM

NORTH AMERICAN AVIATION, INC. SPACE and INFORMATION SYSTEMS DIVISION

Land Landing

n –

n Analysis

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Final Report

Preliminary Definition Phase
Apollo Extension System
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LAND LANDING SYSTEM
PROGRAM ANALYSIS

18 February 1966

Approved by

L.M. Tinnan
Program Development Manager

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ABSTRACT

This document describes the land landing system candidate configurations investigated during the PDP. An analysis of the impact of each configuration in the fields of program management, system development, development test, manufacturing, checkout and field operations, logistics, facilities, and program schedules is presented in detail.

FOREWORD

This document is submitted by the Space and Information Systems Division (S&ID) of North American Aviation, Incorporated, to the National Aeronautics and Space Administration Manned Spacecraft Center in partial fulfillment of the final reporting requirements of Contract NAS9-5017, "Preliminary Definition Study for Utilization of CSM for AES."

Reports being submitted under the subject contract are listed below. Data resulting from subcontractor studies or provided by other sources external to S&ID are included in the appropriate volumes. The reader is urged to refer to other documents in the final report series for further information not contained in this document.

Report No.	Title
SID 65-1145	Master Program Plan (Preliminary)
SID 65-1146	Manufacturing Plan (Preliminary)
SID 65-1147	Facilities Plan (Preliminary)
SID 65-1148	General Test Plan (Preliminary)
SID 65-1150	Configuration Management Plan (Preliminary)
SID 65-1151	Baseline Ground Operations Requirements Plan
SID 65-1517	Program Summary
SID 65-1518	Technical Summary
SID 65-1519	Subsystems Summary
SID 65-1520	Guidance and Control System
SID 65-1521	Communications and Data System
SID 65-1522	Instrumentations, Displays, and Controls
SID 65-1523	Environmental Control and Life Support Systems
SID 65-1524	Thermal Analysis
SID 65-1525	Power Generation and Distribution Systems
SID 65-1526	Cryogenic Storage System
SID 65-1527	Service Propulsion System
SID 65-1528	Reaction Control System
SID 65-1529	Spacecraft Design Summary
SID 65-1530	Structural Loads and Criteria
SID 65-1531	Structural Analysis
SID 65-1532	Mass Properties
SID 65-1533	Earth Recovery System
SID 65-1534	Systems Analysis Summary
SID 65-1535	Reliability Summary
SID 65-1536	Experimenters Design Guide

Report No.	Title
SID 65-1537	Experiment Identification Descriptions
SID 65-1539	Ground Support and Logistics
SID 65-1541	Interface Methodology
SID 65-1542	Functional Flow Diagrams—Lunar Polar Orbit Reference Mission
SID 65-1543-1	Allis-Chalmers Fuel Cell Study—Technical Summary
SID 65-1543-2	Allis-Chalmers Fuel Cell Study—Program Analysis
SID 65-1544-1	Land Landing System—Technical Summary
SID 65-1544-2	Land Landing System—Program Analysis
SID 65-1545-1	Phase I Experiments Integration—Program Analysis
SID 65-1545-2	Phase I Experiments Integration—Cost Data
SID 65-1546	Final Briefing
SID 65-1547	Performance Analysis Phase II Flights
SID 65-1571	Program Costs
SID 65-1723	Mission Description—Flight 211
SID 65-1724	Mission Description—Flight 507
SID 65-1725	Mission Description—Flight 509
SID 65-1726	Mission Description—Flight 511
SID 65-1727	Mission Description—Flights 214/215
SID 65-1728	Mission Description—Flights 216/217

CONTENTS

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ILLUSTRATIONS

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TABLES

INTRODUCTION

For the past several years, NASA has investigated various techniques for incorporating a land-landing capability in the manned space program. The achievement of this capability would provide NASA with an operational flexibility that has not been heretofore possible.

The AES program will include a number of earth and lunar orbit missions not currently considered under the Apollo program. Of these, the earth polar and synchronous orbit flights will present recovery operations that are complex and restrictive if only the current water landing capability of the Apollo is maintained. The application of land landing capability to AES could, therefore, provide desirable solutions to near-term operational problems.

Various systems concepts have previously been investigated by NASA, including both drag and lifting devices. For example, the Ballistics Orbital Support Operations Study, recently performed by S&ID under NASA Contract NAS9-3487, investigated the application of paragliders, rotor system, hot air balloons, and steerable parachutes. As a result, several promising land landing systems concepts were revealed. More recently, NASA has indicated interest in a limited number of land landing concepts that could be applied to the AES program. A study was carried out under Contract NAS9-5017 to investigate the design and development characteristics resulting from the integration of each of these NASA-specified concepts into the AES CM.

One of the primary objectives of the study was to provide sufficient technical and programmatic data such that the NASA could make a comprehensive comparative evaluation of the concepts investigated so as to determine future courses of action. Specifically, NAA was directed by NASA not to make a system selection as a result of this study. The NASA also directed that the operational aspects of recovery be de-emphasized in order to concentrate maximum effort on the system design, CSM integration, and program planning aspects of each concept.

The study was conducted in two distinct phases. The first phase, "Concepts Development," included the parametric analysis of a number of variations within each of the above three concepts. The results of the first phase were presented to NASA at a mid-term briefing, including NAA-recommended concept baselines. As a result of this presentation--and with NASA concurrence--four land landing system concepts were identified to be investigated further in the second, or "Configuration Design and Integration" phase.

The Land Landing System program analysis--which is reported in this document--has placed primary emphasis on those tasks needed to form the basis for evaluation of the program impact on AES Phase II CSM design, development, and production baselines. The study end-products include the preliminary program planning data needed to define the required activities for subsequent program phases. To achieve an adequate understanding of the program implications, it was necessary to identify the changes required to the Command Module, GSE, and mission support systems created by substituting these land landing systems concepts for the unmodified Block II Earth Recovery System which is employed in the baseline AES CSM.

Program analysis was aimed primarily towards determining the spacecraft modifications required for integration or each of the concepts into the AES Phase II vehicle, and to defining the program plans for the development of each LLS concept. These analyses included the areas of Engineering Development and Test, Manufacturing, Test Operations, Logistics Support, and Facilities Utilization. Variations in program requirements were based upon the results of the engineering studies presented in Report SID 65-1544-1, "Land Landing System - Technical Summary." Cost data associated with these requirements are contained in Report SID 65-1571-1, "Program Costs Supplement."

An analysis of the impact on AES schedules was performed to determine requirements for utilization of facilities, required lead times for subsystems, and other pertinent items, and to identify the earliest calendar date that the Land Landing System could be incorporated into the AES spacecraft.

For the purpose of the program analysis activity reported herein, the following guidelines were applied:

1. Assume completion of an FDP with 70% development engineering, and all spacecraft Part I CEI Specifications complete.

2. Phase D go-ahead 1 November 1966.

3. Assume availability of the Saturn V booster assignment required for CM heat shield high heat rate re-qualification test.

4. AES/MDS 11-2 (dated 11-4-65) is the basis for all schedule analyses.

The Pioneer Parachute Co. and Northrup-Ventura were engaged to support the technical study and program analysis for the steerable recovery parachute system concepts. Program planning factors from each of these suppliers have been integrated into this report where appropriate.

SYSTEM DEVELOPMENT

Four basic LLS configurations were selected, with NASA concurrence, for design integration and program planning analysis purposes. These basic LLS concepts, as indicated in Figure 1, are briefly described in this section, along with a discussion of the requisite developmental steps required to assure the availability of man-rated space-qualified LLS hardware.

LLS CONFIGURATIONS

Brief descriptions of the design and operating characteristics of each of the four LLS concepts and the required changes to the Command Module design associated with each are presented in following paragraphs. Reference to SID 65-1544-1 should be made for further design/performance characteristics data.

CONFIGURATION I

Configuration I (Figure 2) utilizes the basic Apollo Parachute System consisting of two mortar-deployed 13.7 ft. diameter drogue parachutes, three mortar deployed pilot chutes, and three pilot chute deployed 83.5 ft. diameter conical Ringsail main parachutes. The three main parachute risers are attached to the Command Module by means of a controllable swivel "flower-pot". (Section D-D in Figure 2) The Block II Apollo proposed retro-rocket system (four Gemini rockets) is incorporated in this concept to reduce landing impact velocity.

Operation

The operational sequence from entry through main parachute disreef, is the same as for Block II Apollo. Upon entering the earth's atmosphere, the increasing atmospheric pressure causes a baroswitch to close at approximately 25,000 ft. altitude. Closure of this (high altitude) baroswitch initiates the time delays which properly sequence forward heat shield jettison followed by drogue mortar fire. The Command Module descends on the two drogue parachutes to an altitude of approximately 11,000 ft. at which point a second (low altitude) baroswitch closes, signalling simultaneous drogue disconnect and pilot chute

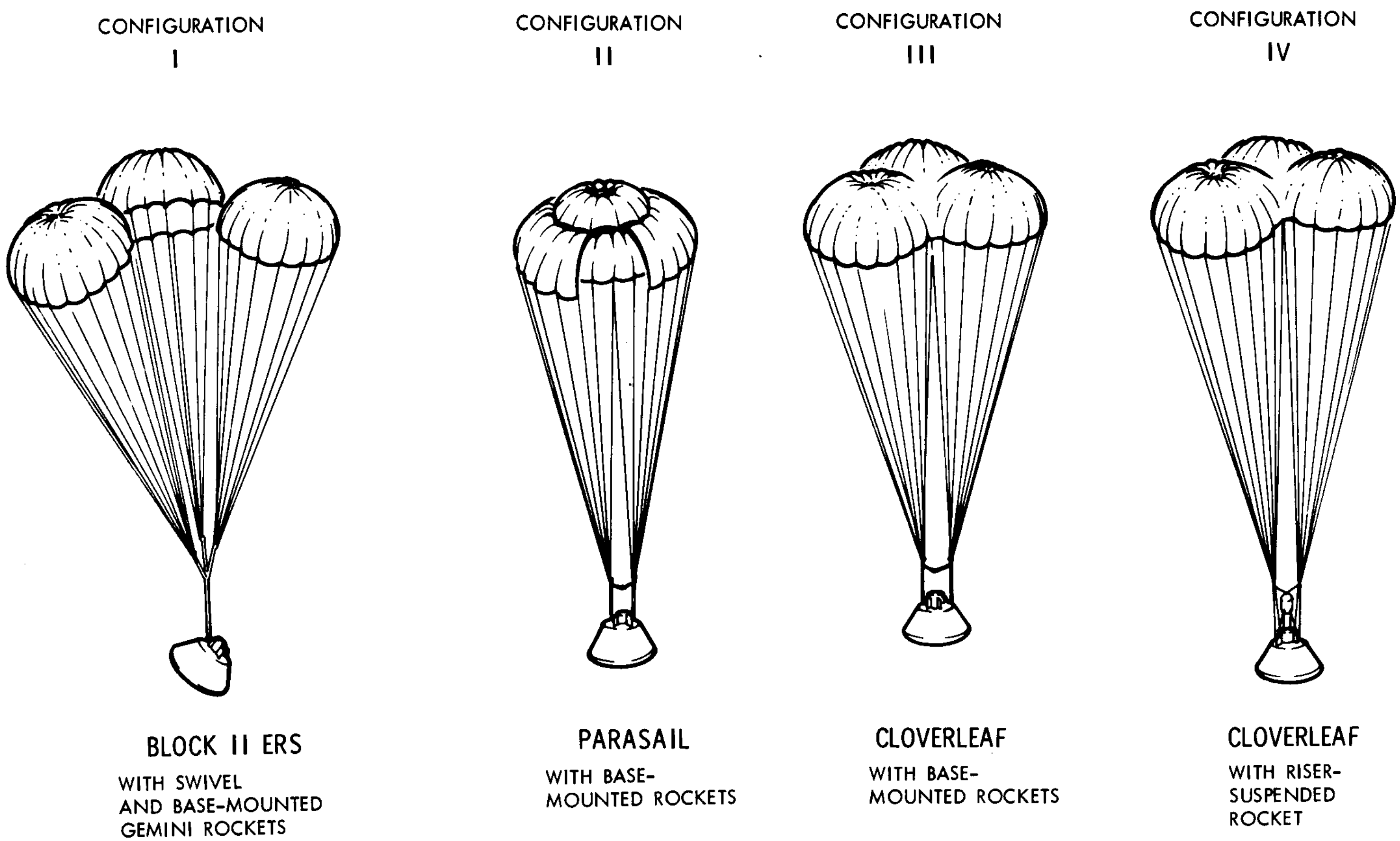

Figure 1. AES/LLS Configurations

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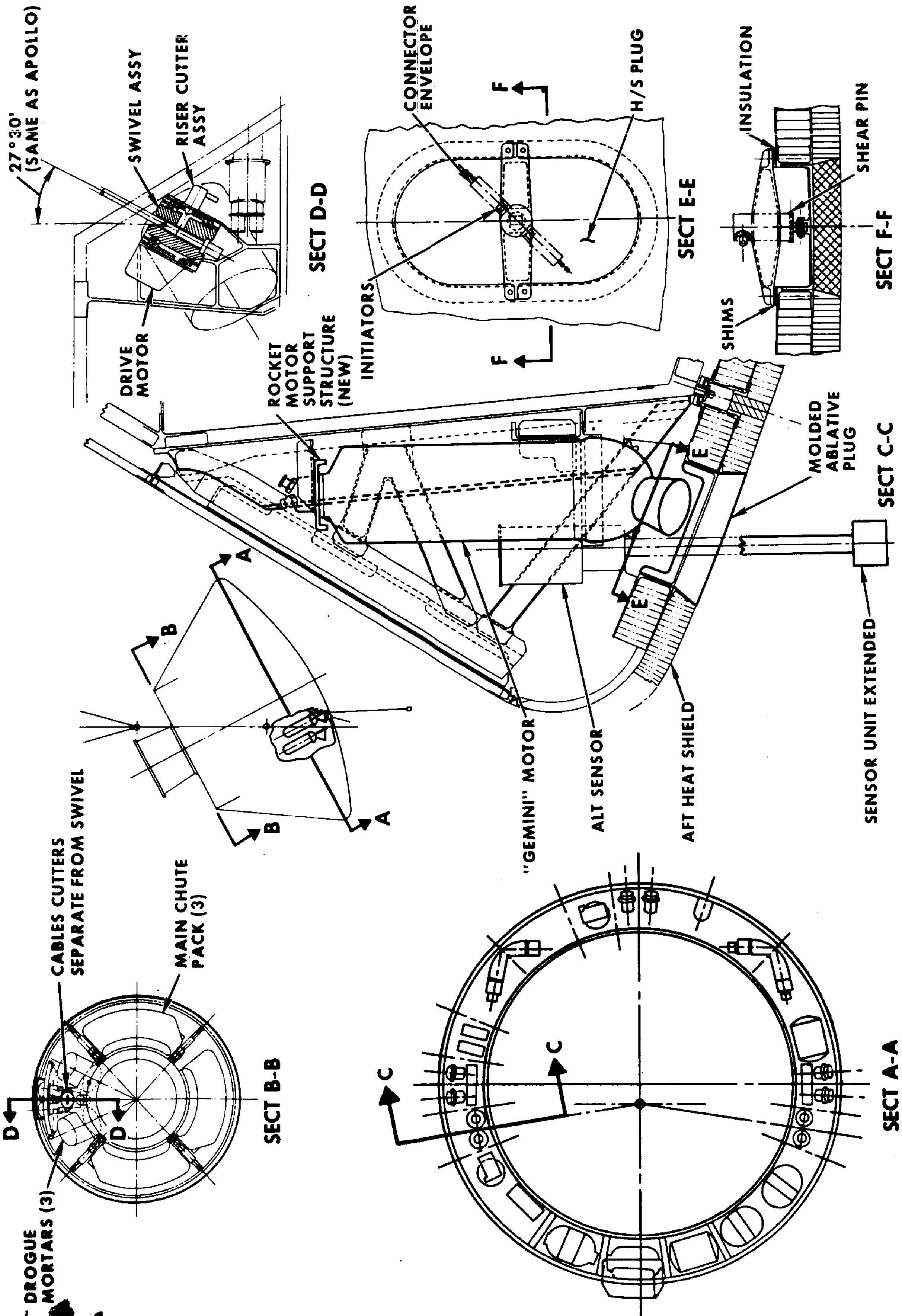

Figure 2. LLS Configuration I

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mortar fire. The three pilot parachutes each deploy one Ringsail main parachute. The mains are at first reefed and remain reefed for a period of eight seconds following line-stretch. For reliability purposes, each main parachute is reefed with dual (redundant) reefing lines, and each line has three cutters.

Subsequent to disreefing of the main parachutes, the Engineer and/or Pilot may observe the ground for a period of three to four minutes to determine the orientation of the vehicle with respect to the direction of wind drift. Wind drift observations are made possible by inclusion of a small mirror mounted in each side window. The mirrors are mounted in such a way that the astronauts in the two side couches can observe the ground from the reclining position.

Sometime during this interval, the control system must be manually switched from the RCS mode to the swivel mode. During approximately the last 2,000 feet (final minute of descent) the controllable swivel will be utilized to roll-orient the vehicle to either plus or minus 40 degrees of roll with respect to the flight path vector. The swivel is controlled by means of the Rotational Hand Controller (after the selector switch has been turned to "Swivel" mode) by simply twisting the controller handle as though issuing an RCS "Roll" Command. Ground impact with the + Z axis aligned 40 degrees off the direction of travel relative to the ground ensures maximum effectiveness of the Impact Attenuation System and prevents loading beyond emergency crew tolerance limits.

Shortly after disreef of the main parachutes, a signal from the sequence controller will initiate deployment of the ground-sensing probes (two redundant 8 ft. long probes with land and water impact switches). Closure of an impact switch on either of these probes will fire the retro rockets, thereby decelerating the vehicle so that vertical velocity (V_V) will be close to zero at ground impact. The Retro System is so designed that in the event of failure of one of the four retro-rockets, V_V will not be sufficiently high to produce accelerations in excess of the emergency crew tolerances at impact.

Required Changes to AES Command Module

Configuration I permits use of the Block II Earth Recovery System without change except for minor modifications to the Sequence Controller and the addition of the swivel. Incorporation of the controllable swivel involves the following modifications:

New rotating "flowerpot", worm drive gear box and electrical motor.

Revised "flowerpot" support structure.

Relocated wiring to recovery system cable cutters.

New wiring from batteries to swivel motor.

Electrical switch on display panel to change from RCS mode to Swivel Control mode when using hand controller, and associated wiring changes.

The Rocket Landing System proposed for Configuration I is identical to the system proposed by NAA/S&ID for Apollo Block II and requires the following C/M modifications:

Modified nozzle assembly and mounting provisions for Gemini rocket.

Mounting provisions for rockets attaching to the inner structure.

Heat shield changes which include holes in heat shield and ablative material in addition to plugs for these holes. Holes are surrounded by new edge members.

Cartridge operated thrusters to push out the plugs and thruster mounted structure attached to heat shield. Inserts are included in honeycomb for attachment.

Mounting provisions for an extending mechanical probe system.

Salt water and impact switches attached to probe.

Wiring changes to include new rocket ignition wires from batteries to impact switch to rockets. Modification of wiring harness in upper corner of aft equipment compartment for rocket installation.

Modification of plumbing around rocket motors.

Relocation of helium tank and plumbing and wiring.

Relocation of flotation system compressor wiring and plumbing.

Relocation of RCS motor switches and associated wiring.

Two new access doors into aft equipment bay.

Elimination of 175 lbs. of structure from the aft heat shield.

Modification of spacecraft sequencing system for rocket system initiation.

Addition of a small mirror to provide visibility from each side window.

CONFIGURATION II

Configuration II (Figure 3) utilizes a steerable gliding main parachute of the Parasail type having a lift-to-drag (L/D) ratio of 1.15. The system includes three mortar deployed Apollo-type drogues which double as the extraction chutes for the 90 ft. diameter Parasail. A back-up system, for use in the event of failure of the Parasail, includes a standard Ringsail parachute of approximately 100 ft. diameter which is pilot chute deployed. The control system which is incorporated in the steerable chute will permit (1) upwind landings, and (2) local obstacle avoidance at impact. The control system is designed to be pilot-operated by means of the existing Rotational Hand Controller which is presently used for the RCS. A closed circuit television system is included for vision purposes, with back-up vision provided by mirrors which permit visibility out of the Command Module side windows.

Controls and display arrangements for astronaut control during the landing phase are shown in Figure 4. The TV screen itself is located <u>behind</u> the control panel and is mounted at an angle of 90° to the surface of the panel. At the time of TV camera and sensor activation, the navigator releases a section of the control panel directly in front of his eyes. This section of the panel will hinge down and lock, revealing a mirror mounted at a 45° angle, thus enabling the navigator to view the TV screen.

Also shown in Figure 4, is a selector switch which enables the rotational hand controller to be switched from the RCS mode to the LLS mode. Turn maneuvers are executed by commanding "Roll" with the Rotational Hand Controller.

A Retro Rocket System is incorporated to reduce vertical velocity and consists of (1) four new (non-Gemini) rockets mounted in the aft heat shield, and (2) redundant altimeters (one radar and one infra-red) and associated logic network which automatically fires the retros at the optimum height above the ground to provide $V_v \approx 0$ at impact. (V_v will not exceed 15 fps, even in the event of failure of any one of the four rockets or of steerable main failure, requiring use of the back-up main.)

<u>Operation</u>

Deployment of the drogues is accomplished in the same manner as described for Configuration I. In this system, however, three drogues are used so that in the event of failure of one drogue to be deployed, the two remaining will suffice to decelerate the vehicle to a sufficiently low dynamic pressure that opening loads on the Parasail will not exceed 26,000 lbs. Like Configuration I, Drogue-disconnect/Parasail-deployment is signalled by closure of the low altitude baroswitch.

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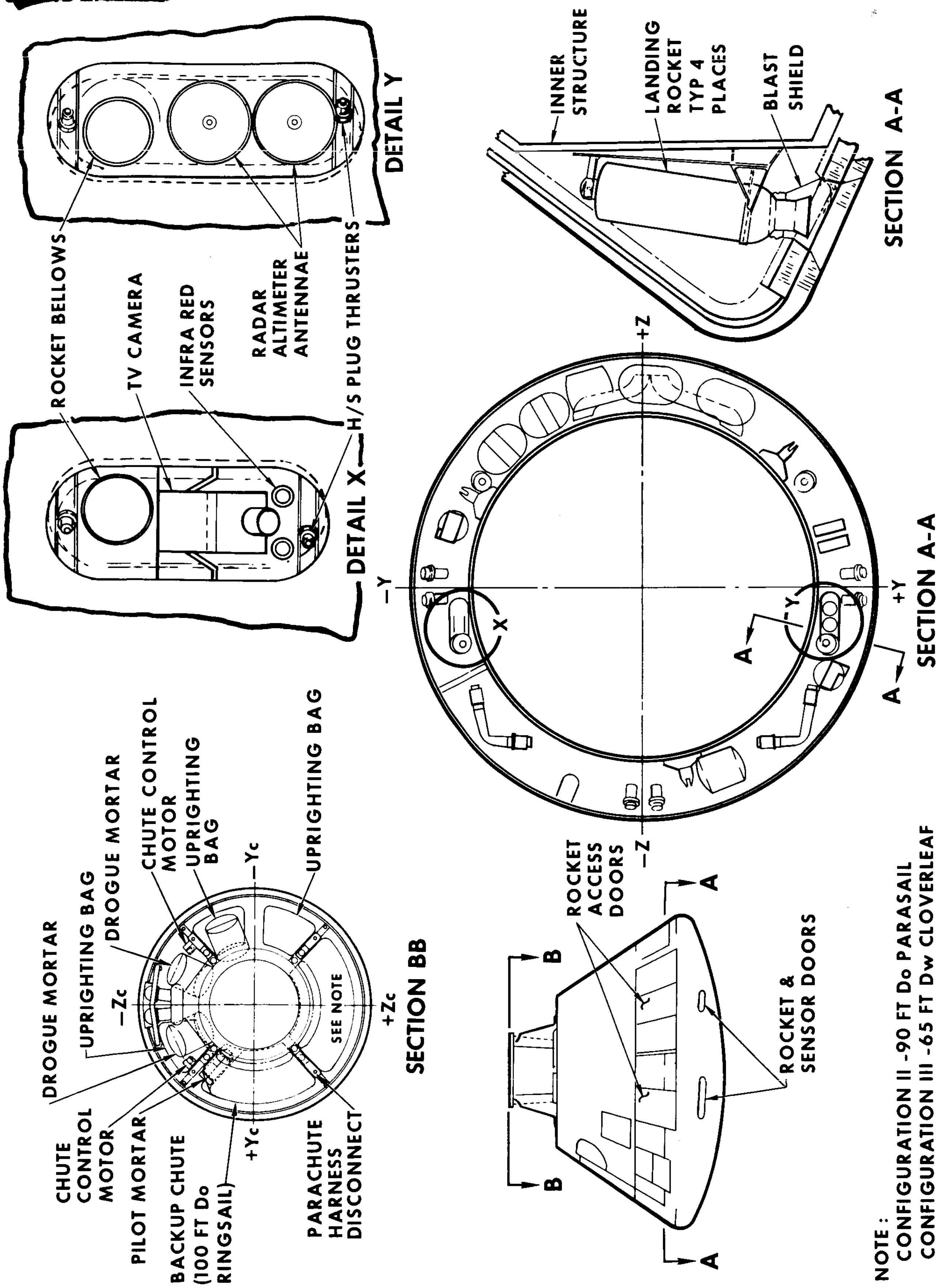

Figure 3. LLS Configuration II

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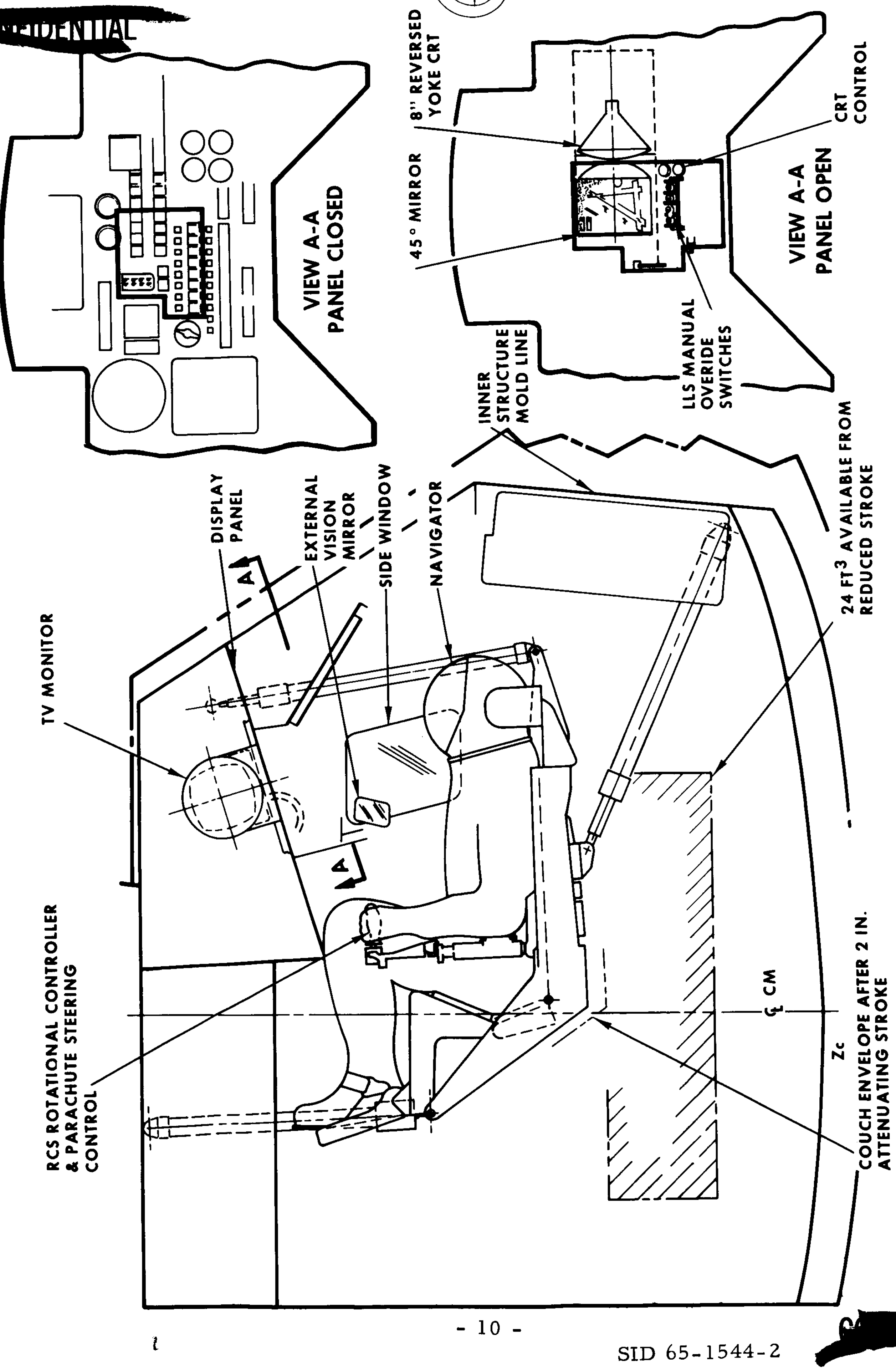

Figure 4. LLS Controls and Displays

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During the time of opening shock loads and reefed main parachute operation, the Parasail is attached to the "flower pot" where adequate structure is provided to sustain high initial loads. Upon reaching terminal descent velocity, the single riser attachment to the "flower pot" is disconnected and the suspension shifts to a four-legged attachment.

Conversion from single-point to four-point attach, is automatic unless delayed by the astronauts by means of a manual override. Thus, if the crew members are not incapacitated, they can delay the suspension shift until such time as a determination has been made that the steerable chute is undamaged, has been properly deployed and is ready to function in the gliding (and steerable) mode.

In the event of steerable chute failure at inflation, the steerable chute will be jettisoned manually and the back-up chute deployed simultaneously. After the back-up chute is fully deployed and final descent conditions achieved, the shift to four-point attach is accomplished. Single point release will initiate heat shield blowout - plug jettison, TV camera and altitude sensors operation, and, after a time delay, arming of the landing retro rockets.

During the descent and maneuver phase, data from the altimeters is fed into logic circuitry in the sequence controller which, in turn integrates rate and altitude data and automatically selects the optimum altitude at which to fire the retro-rockets. The retros are designed to decelerate the vehicle from $V_v = 30$ fps to $V_v = 0$ so that when all four retros fire properly, touchdown occurs with essentially zero descent velocity. Even with failure of one of the four retros, V_v will be less than 15 fps at touchdown.

By means of the TV system, wind drift will be determined and a landing area selected. The navigator will steer the system to the target area and land up-wind, thus minimizing horizontal velocity (V_H) at impact. The TV System is sufficiently versatile so that a gross landing area can be selected from altitudes as high as 10,000 ft., and local obstacles such as slopes, trees, etc., can be recognized and identified at an altitude of 2,000 ft.

Required Changes to AES Command Module

Changes to the AES Command Module required to incorporate the retro system are detailed below:

Mounting provisions for attaching rockets to inner structure. (Similar in detail to proposed Apollo rocket mounting.)

Heat shield changes which include holes in honeycomb heat shield and ablative material. This design is similar to that proposed by Apollo.

Cartridge operated thrusters to push out the plugs, and thruster mounting structure attached to heat shield. Honeycomb inserts are required.

Modification to wiring harness and plumbing in rocket area.

Wiring for TV, Radar, Infra-Red Systems and four Rocket Ignition.

Relocation of helium bottle, oxidizer tank, potable water tank and flotation system compressor with associated plumbing, wiring, and mounting structure.

Frame 10 modified. Four honeycomb cores in toe modified to become Frames 4, 5, 6, 7, and 8.

Four new access doors into aft equipment compartment.

Elimination of 200 lbs. of structure from aft heat shield.

Modification of spacecraft sequencing system for rocket system.

The following changes to the Command Module are required for installation of the Ground Sensing System:

Mounting structure for altimeter sensors in one heat shield plug area.

Add bolt-on provisions to sequence controller for mounting of electronic box.

Structural modification to display panel for installation of door and mounting provisions for TV screen behind panel. Associated changes to existing switch wiring to allow door to open.

Mounting of two small mirrors in side windows.

For incorporation of the new parachute system, the modifications to the vehicle are:

Addition of parachute harness attached to four pyrotechnic disconnects in gussets.

Relocation of flotation system bags.

Revision of "flower pot" and cable cutters.

Addition of a new mortar and support structure to tunnel and parachute deck.

Modified sequence controller.

Addition of two motorized winches to gussets or deck of parachute compartment with associated wiring to batteries.

Addition of switch on panel to change from RCS mode to parachute control (or LLS) mode when using hand controller.

CONFIGURATION III

Configuration III is identical to Configuration II in all respects (Figure 5) except that the Parasail parachute of Configuration II is replaced by a steerable parachute of the Cloverleaf type. The Cloverleaf parachute has a space variable L/D capability over the range 0.6 to 1.4. In this configuration, it is planned to utilize the two extremes; landing at maximum L/D in high-wind conditions, and at minimum L/D on calm days. This L/D modulation capability ensures minimum horizontal velocity under all landing conditions, thereby reducing the possibilities of post-impact tumbling.

The particular Cloverleaf being analyzed for AES has a diameter of 80 ft. and will provide a terminal rate of descent not to exceed 30 fps. The weight and volume characteristics of the Cloverleaf are identical to those of the Parasail of Configuration II.

Operation and Changes to AES Command Module

The only significant difference between Configurations II and III from the standpoint of their impact on the Block II Command Module is that the Rotational Hand Controller will be wired to permit Cloverleaf L/D modulation as well as steerability when the selector switch is turned to the LLS mode. This will be accomplished by utilizing the "pitch control" aspect of the Rotational Hand Controller. All other Command Module modifications will be as described for Configuration II.

CONFIGURATION IV

Configuration IV (Figure 6) is the same as Configuration III with two exceptions. First, instead of four retro-rockets mounted in the aft heat shield, a single retro-rocket is provided. It is initially stowed in the recovery compartment and deployed by the parachute harness above the airlock. Second, to eliminate the need for redesigning the aft heat shield, the two altimeter antennae and the TV camera are mounted on an existing lower equipment bay panel which is hinged to rotate out of the side of the Command Module.

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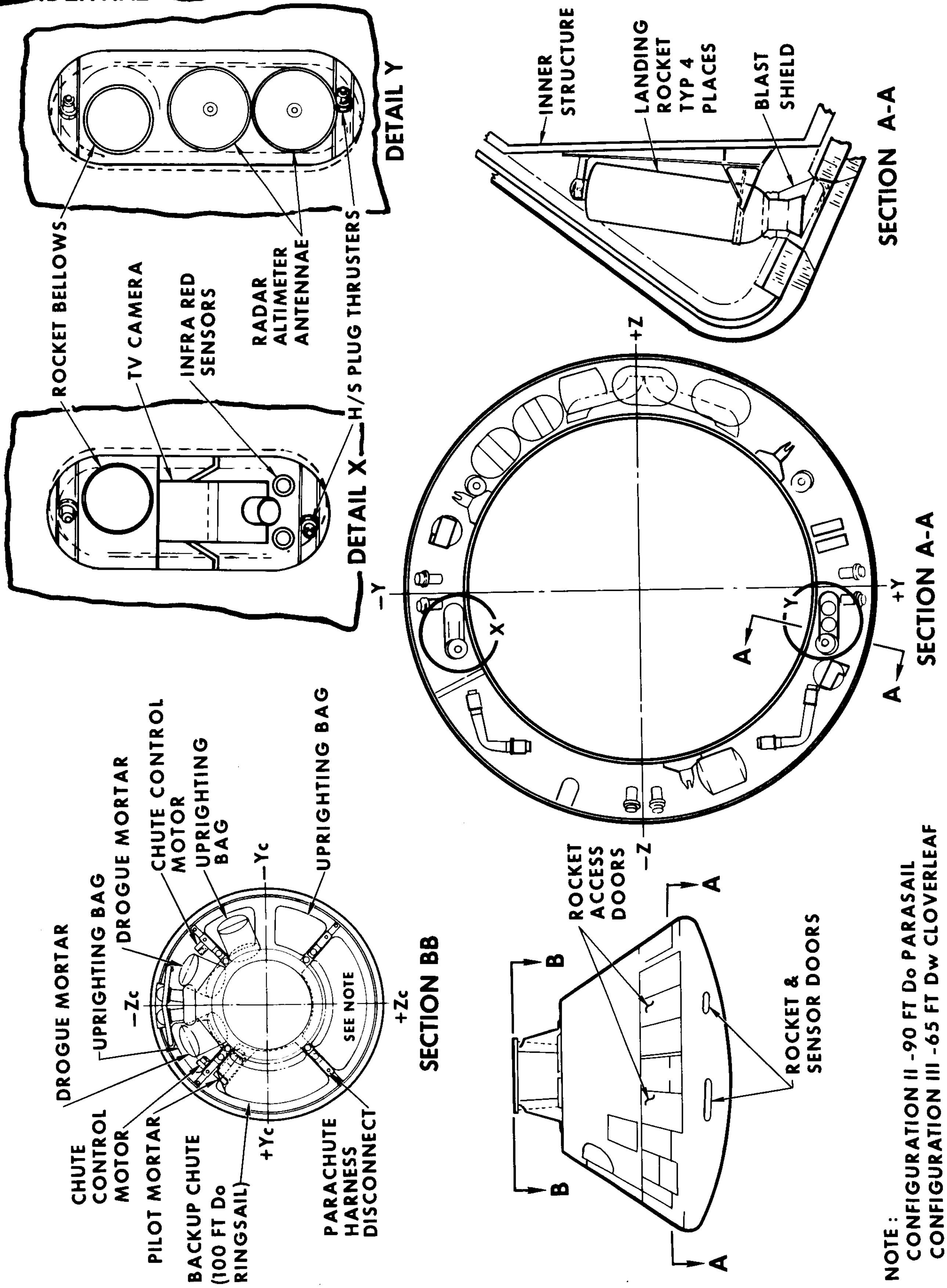

Figure 5. LLS Configuration III

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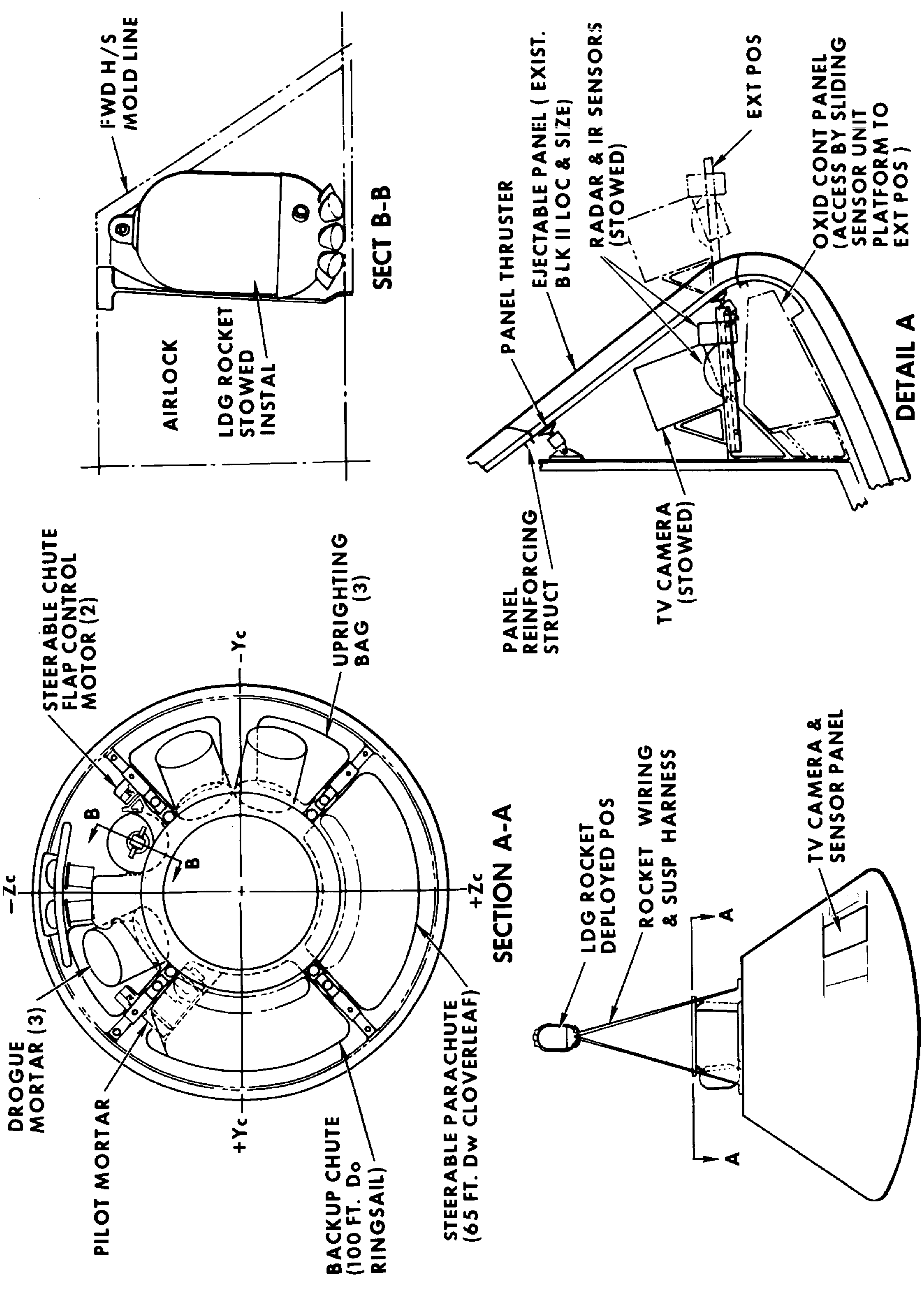

Figure 6. LLS Configuration IV

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This location will allow sensor accessibility after the stack is assembled on the pad.

Operation

The operation of this system, from the standpoint of astronaut control, is identical to that of Configuration III. The TV camera and altitude sensors are automatically deployed by the sequence controller. Deployment of the riser suspended retro-rocket occurs at the time the parachute suspension is shifted from single point attachment at the "flower pot" to the four-point suspension of the gliding mode. As with Configurations II and III, shift from single point to four point suspension is automatic unless purposely delayed by the astronauts via the manual override switch. Thus, even in the event of an incapacitated crew, the retro will be deployed and ready to function prior to impact.

Considerations regarding the use of the back-up parachute system are the same as described for Configurations II and III. The decision of whether or not to jettison the steerable chute and deploy the back-up must be made prior to converting from single-point to four-point attach.

Changes to AES Command Module

Changes to the Command Module required for incorporation of the riser-suspended retro are listed below:

a) Rocket mounting cradle on parachute deck.

b) Additional harness lines for rocket suspension.

c) Wiring addition for rocket ignition.

d) Relocation of drogue mortar to - Y bay.

Command Module changes associated with the Ground Sensing and Visions Systems are:

a) Beef up of structure around access panel.

b) Hinge access panel.

c) Add support structure to inner mold line of access panel for mounting sensors.

d) Add silicone rubber strip imbedded in ablative material around periphery of panel similar to proposed Apollo rocket plugs.

Changes inside the Command Module for the TV system screen and parachute control are the same as for Configuration III. Similarly, parachute control and changes for the parachute system are the same as for Configuration III except for the additional wiring harness required.

DEVELOPMENT ENGINEERING

ADDITIONAL FDP ANALYSIS

Definitive recovery system design criteria would be generated during FDP for use by the subcontractors and S&ID to serve as a guideline in the performance of system analysis, reliability analysis, detail design and test planning.

Recovery requirements and system considerations will have to be integrated into the design criteria. Installation and accessibility requirements as well as the weight, volume, and location of the landing system components will need to be determined. The recovery system and attenuation system loads and stress requirements, as well as the subsystem structural interface requirements, would additionally be defined. The mass characteristics of subsystem components will be incorporated in the total mass properties of the spacecraft; these will include weight, center of gravity, and moment of inertia. Analysis of crew displays and visibility systems initiated during the PDP will be continued and the performance of these systems with regard to spacecraft suspension angle, required terrain resolution, landing system performance, and landing operations data would be analyzed.

Further recovery system and vehicle control analysis will define maneuver activities during the final landing phase. Methods for control will be determined based on the participation levels of crew and ground stations in the final landing phase. Specific requirements for ground sensing devices required for landing retro-rocket ignition will also be defined.

Analysis of ground support equipment requirements and the mobile ground station will be continued during the FDP, to further refine their definition and permit the preparation of design data to support procurement during the Development Operations Phase.

DESIGN

The Land Landing System must be designed to meet the previously established design requirements. Preliminary layouts for the major subsystems such as the recovery system, impact attenuation system, crew control system, CM structure modification, etc., will be prepared. The layouts and data will include definition of the external and internal arrangements for the Command Modules of the LLS and will be of such depth that a firm basis for the detail design of the LLS to be performed in Phase D is provided. Layouts prepared will define the configuration and installed location of the various subsystems components, the structure for support of the components and the provisions for their installation and maintenance. All significant valving, plumbing and wiring will be shown. Layouts will also define basic load paths for both primary and secondary structure, where changed for Block II, and

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approximate member sizes required. Fabrication and assembly techniques will be considered and given preliminary definition on the layouts. The drawings and data generated will become inputs to the various specifications prepared during the FDP.

STEERABLE PARACHUTE DEVELOPMENT

During the preliminary definition phase of the LLS, two suppliers of steerable-parachute recovery systems provided conceptual design and program data to NAA: the Pioneer Parachute Company (Parasail) and the Northrop Corporation, Ventura Division (Cloverleaf).

These suppliers have been provided with design criteria, program schedule requirements and other program data necessary to conclude the required development program during the final definition phase. Parachute test requirements as related to supplier requirements are presented in the Development Test portion of this section together with the scheduled test activities.

The Land Landing Study Integrated schedules 1-1B through 1-1D, Figures 8 through 10, contain the specific parachute system schedule milestones, while the master schedule, Figure 37, contains a summary test schedule. Supplier schedule data supplied to NAA during the PDP has been taken into consideration in the preparation of these schedules. Supplier schedule data is in consonance with the total NAA program schedule requirement.

Continuation of supplier activity will depend upon the ultimate selection of a specific land landing system configuration.

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DEVELOPMENT TEST REQUIREMENTS

The Land Landing System test program encompasses three major areas which constitute the development cycle: 1) Development Tests, 2) Qualification Tests, and 3) Integrated Tests.

Development testing is essentially divided into three major areas which can be described as follows:

> Prototype Bench Tests - These are generally tests conducted on assemblies or subassemblies which are initially tested individually then integrated as a unit in order to verify design parameters or to identify design problem areas.
>
> Environmental Tests - These are laboratory tests conducted on complete preproduction components by exposing these components to simulated various storage, launch, flight and entry environments and determining the suitability of the components after exposure.
>
> Functional Tests - All components are required to meet specific functional requirements after environmental exposure. These tests will verify the functional integrity of the system.

The scope of the development testing program will encompass the following objectives:

1. Evaluation of materials, parts, components, and circuits to determine their compatibility with the overall design.

2. Acquisition of design or process information by testing under normal and/or off-limit conditions to acquire data pertaining to limiting loads, dynamic stresses, material degradation, and failure modes.

3. Assurance that the product will successfully complete the qualification tests.

In addition to the laboratory tests, some tests will be conducted in the field utilizing a cylindrical bomb and Parachute Test Vehicle (PTV) to develop design information for the parachute systems. These tests will be conducted at the El Centro Facility.

QUALIFICATION TESTS

A qualification test program will be required on production hardware at and above mission levels of all critical environments to assure that the hardware will 1) meet the design requirements, and 2) perform its function for its use cycle. The program will be limited to tests conducted on individual parts, components, subassemblies, assemblies and subsystems, and will consist of a series of tests at the highest practical level of assembly. If tests at several levels are required, those at the lower level are to be initiated before those at the higher assembly level.

The qualification test program is divided into laboratory environmental testing and flight testing areas. As a general rule, it is not economically practical or feasible to conduct qualification tests on complete subsystems. Therefore, most of the qualification tests will be conducted on lower levels of assemblies as necessary to provide a high degree of confidence on a subsystem basis.

In addition to the laboratory qualification program, a series of flight qualification tests will be conducted with boilerplate vehicles to assure that the subsystem can successfully function under the various modes of recovery. These tests in addition to the laboratory qualification test on hardware items, will complete the qualification testing cycle and will provide adequate assurance of the reliability of the system.

INTEGRATED TESTS

These tests are in addition to the laboratory and flight test qualification program and are designed to test the entire Land-Landing System concept as an integrated unit. In this series of tests, there will be four test areas as follows:

<u>Interface Compatibility Tests</u>

These tests will be conducted on house spacecraft or C/M mock-up to verify electrical, mechanical and/or hydraulical compatibility of the various systems when assembled into the C/M vehicle system. In addition, these tests will identify problem areas which were not readily evident in the development and testing of the individual systems.

<u>Boilerplate Tower Drop Tests</u>

These tests will consist of a series of drop tests from the NAA/S&ID Tower Facility utilizing a C/M boilerplate vehicle which will be complete with the exception that no parachute system will be utilized. The tests will verify the function of the Ground Sensing Systems, Crew Vision Systems, Sequencer Controller System, and Retro-Rocket System as a complete and integral system.

<u>Boilerplate Aerial Drop Tests</u>

These tests are to be conducted at the El Centro Facility utilizing a C/M boilerplate vehicle complete with the entire Land-Landing System including parachutes. The vehicle will be dropped from a C-133 Aircraft, the system operated from the Mobile Ground Station, and the functions of all systems monitored to determine if the established requirements are met.

Unnamed Flight

Most of the components comprising the LLS will have been qualified in either laboratory or flight drop tests. However, the modified aft heat shield and ablative heat shield plugs of Configurations I, II, and III, cannot be qualified by these ground tests along, since re-entry heat (and other conditions) cannot be simulated in laboratory tests. An unmanned spacecraft flight with the entire land landing system will be required to complete qualification.

This flight will utilize a spacecraft which has been built (or modified) to meet AES requirements. Aside from monitoring normal CM operations, it will be instrumented to detect any changes in the heat shield characterisitics due to the addition of blowout plugs. In particular, 1) any tendency of the ablative material to "flow" when subjected to re-entry heat, 2) the degree of fusing between ablative plugs and surrounding ablative material, and 3) separation characteristics.

Trajectory analysis has shown that satisfactory heating conditions can only be attained with a highly elliptical orbital return. A Saturn V launch vehicle will be required for this flight.

The successful termination of this unmanned flight with safe land landing will mark the completion of the LLS development program and effectively qualify it for future AES manned flights.

TEST CONFIGURATION AND SCHEDULES

This specific test program is directed toward the complete testing of four separate and distinch land landing configurations. Included are:

I. Apollo Block II Earth Recovery System w/Swivel and Base-mounted Retro-Rockets

II. Parasail Earth Recovery System w/Base-mounted Retro-Rockets

III. Cloverleaf Earth Recovery System w/Base-mounted Retro-Rockets

IV. Cloverleaf Earth Recovery System w/Riser-mounted Retro-Rockets.

The Integrated Schedules (Figures 7, 8, 9, and 10) include the development test requirements for each LLS concept as well as the types of test required, vehicles and subsystems required to complete the tests. A later section of this report further describes the test program implementation.

MOBILE GROUND STATION (MGS)

During the development of test requirements for the land landing system, it was determined that control and monitor activities would be required to support the aerial drop tests and land landing unmanned flight test. To satisfy this requirement, the MGS was conceived and planned to support the development test activities for all LLS configurations.

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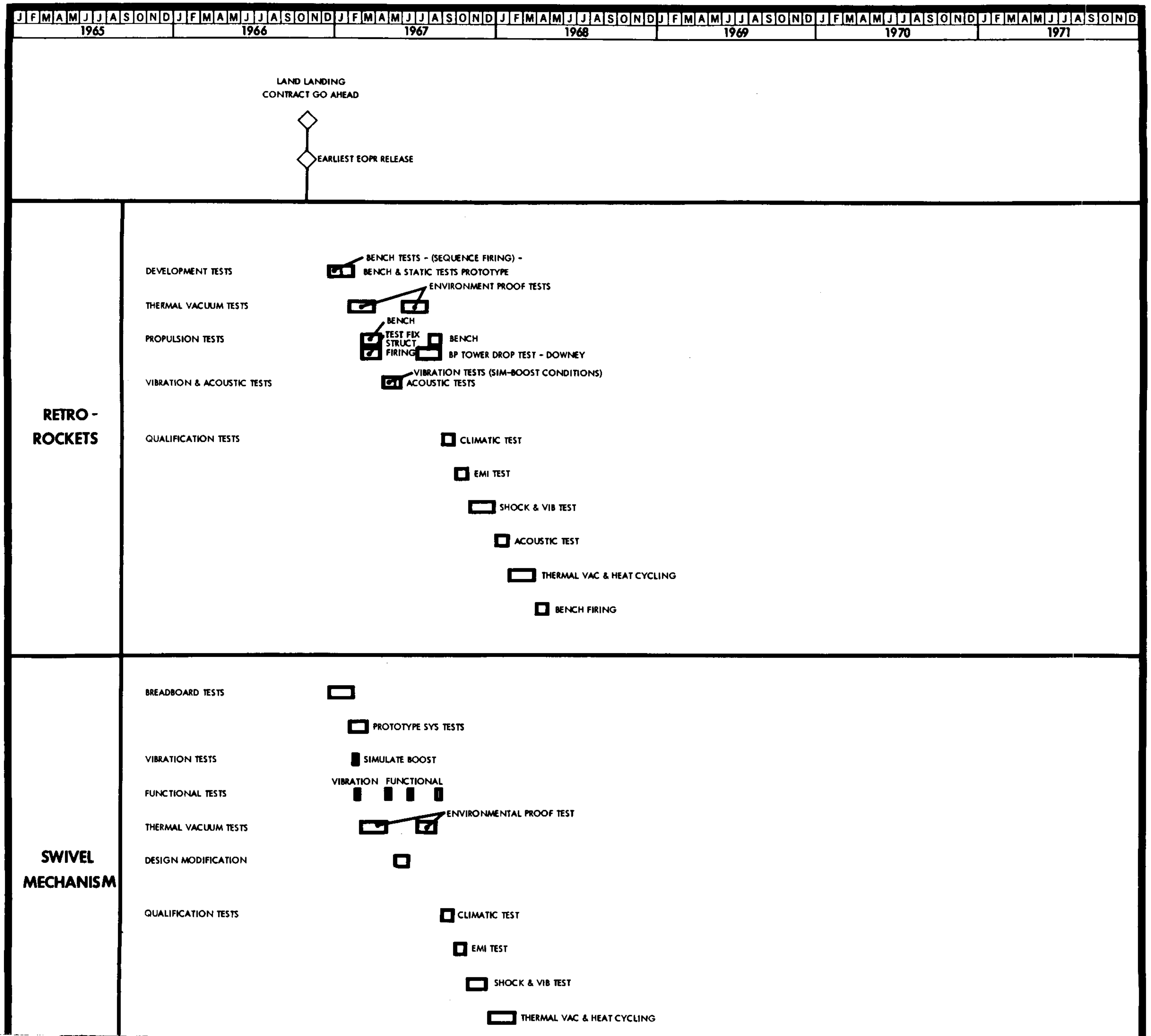

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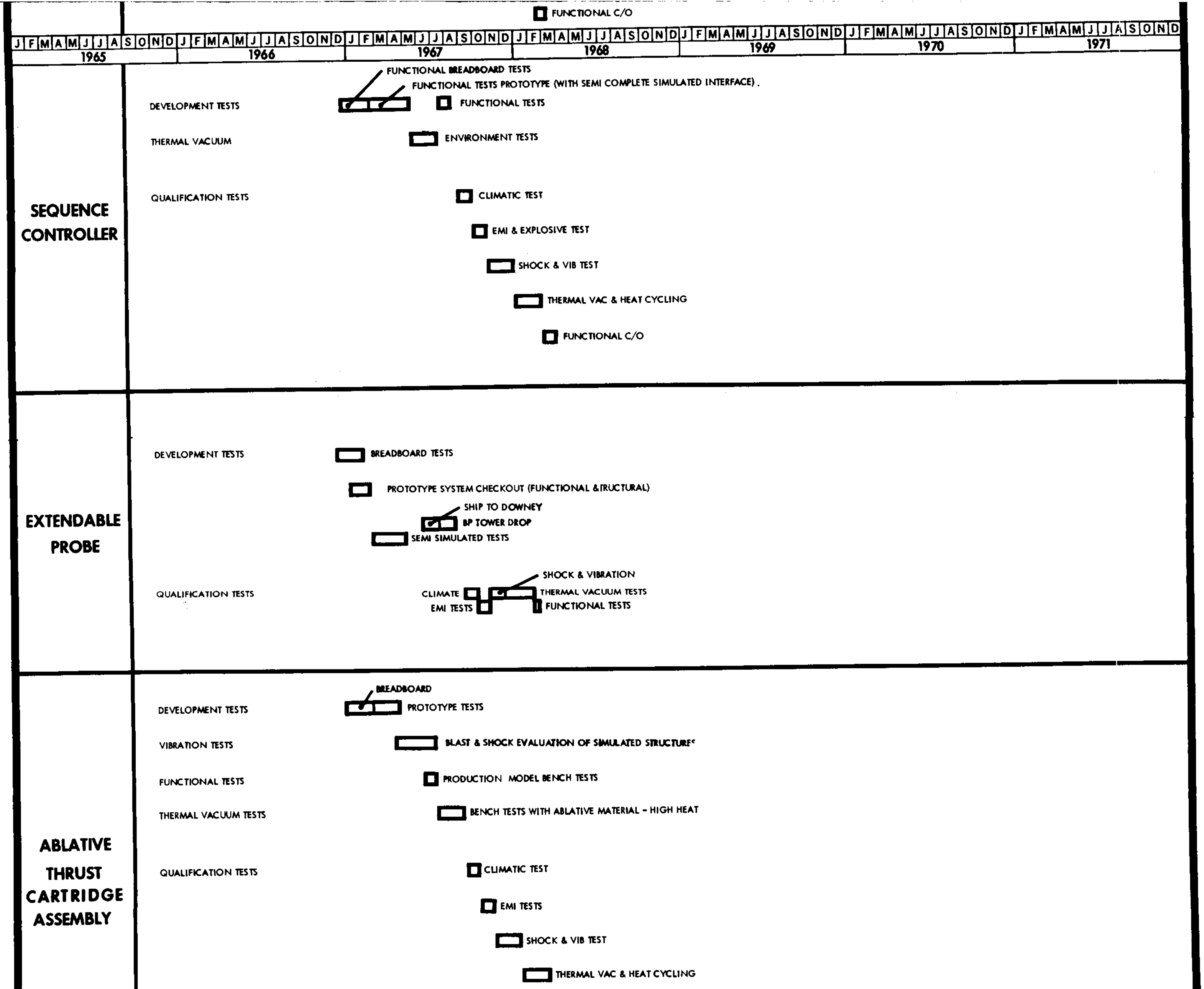

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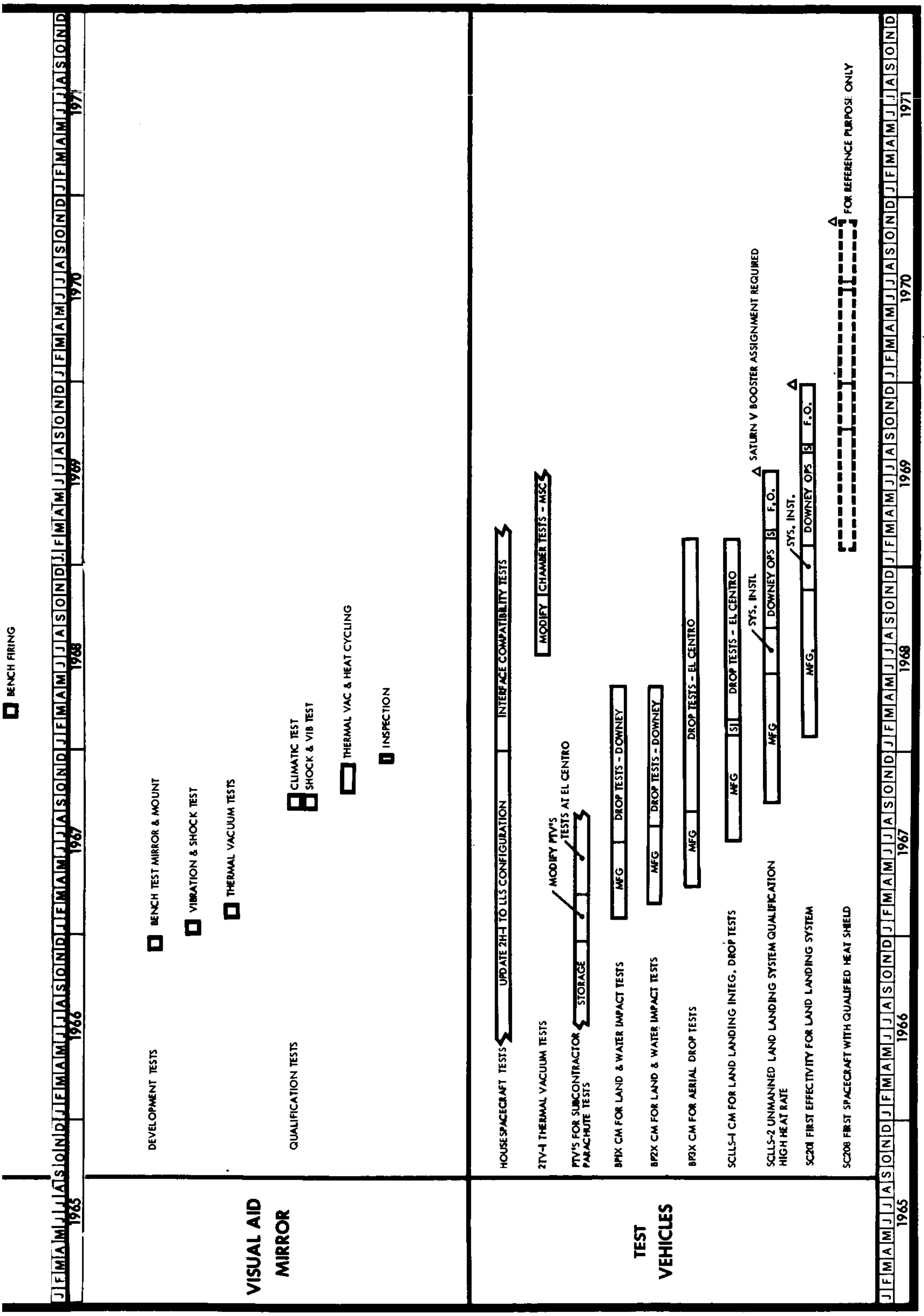

Figure 7. Integrated Schedule - LLS Configuration I

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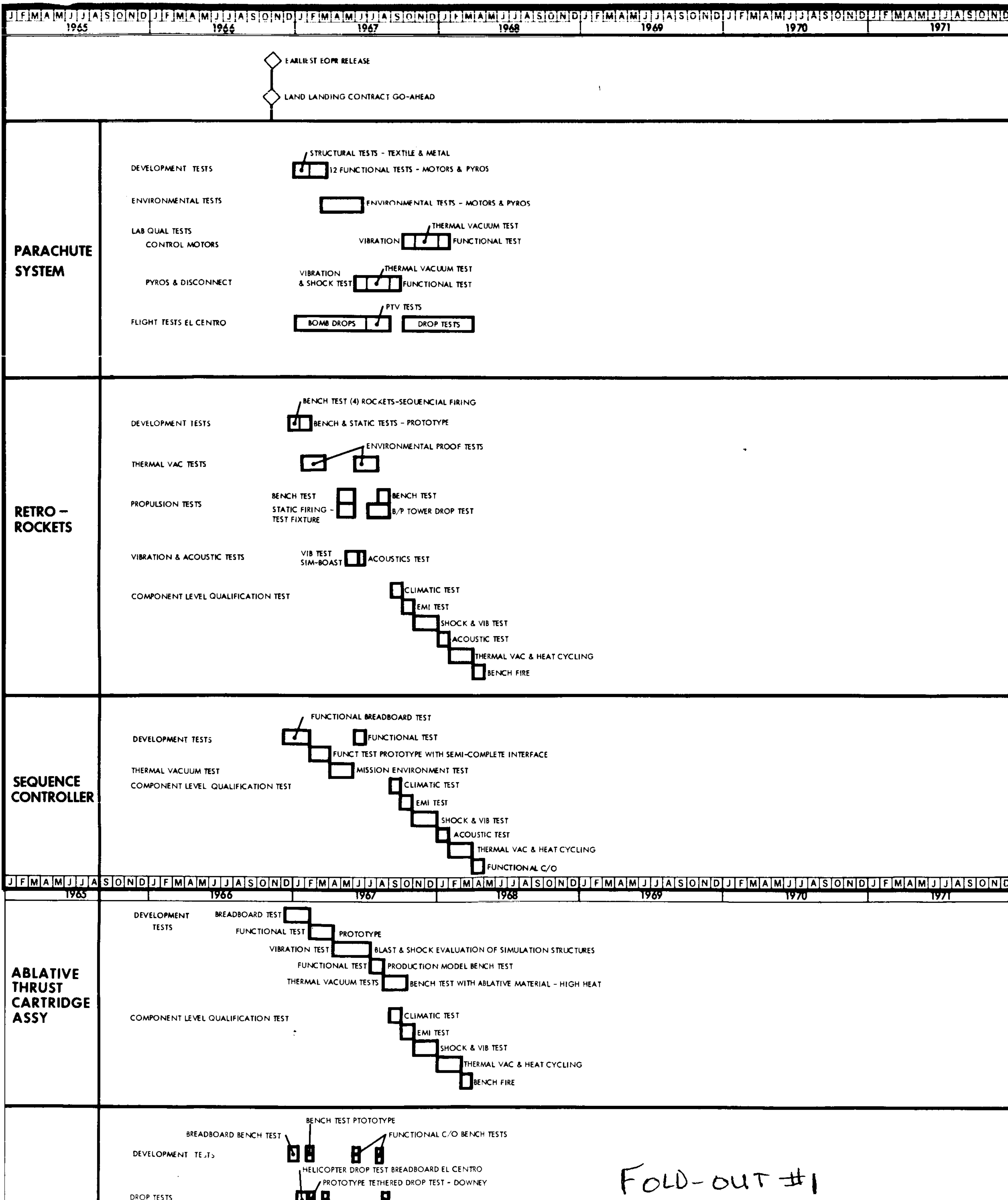
J F M A M J J A S O N D (repeated for each year)
1965
1966
1967
1968
1969
1970
1971
EARLIEST EOPR RELEASE
LAND LANDING CONTRACT GO-AHEAD
PARACHUTE SYSTEM
DEVELOPMENT TESTS
STRUCTURAL TESTS - TEXTILE & METAL
12 FUNCTIONAL TESTS - MOTORS & PYROS
ENVIRONMENTAL TESTS
ENVIRONMENTAL TESTS - MOTORS & PYROS
LAB QUAL TESTS
CONTROL MOTORS
VIBRATION
THERMAL VACUUM TEST
FUNCTIONAL TEST
PYROS & DISCONNECT
VIBRATION & SHOCK TEST
THERMAL VACUUM TEST
FUNCTIONAL TEST
FLIGHT TESTS EL CENTRO
BOMB DROPS
PTV TESTS
DROP TESTS
RETRO - ROCKETS
DEVELOPMENT TESTS
BENCH TEST (4) ROCKETS-SEQUENCIAL FIRING
BENCH & STATIC TESTS - PROTOTYPE
THERMAL VAC TESTS
ENVIRONMENTAL PROOF TESTS
PROPULSION TESTS
BENCH TEST
STATIC FIRING - TEST FIXTURE
BENCH TEST
B/P TOWER DROP TEST
VIBRATION & ACOUSTIC TESTS
VIB TEST SIM-BOAST
ACOUSTICS TEST
COMPONENT LEVEL QUALIFICATION TEST
CLIMATIC TEST
EMI TEST
SHOCK & VIB TEST
ACOUSTIC TEST
THERMAL VAC & HEAT CYCLING
BENCH FIRE
SEQUENCE CONTROLLER
DEVELOPMENT TESTS
FUNCTIONAL BREADBOARD TEST
FUNCTIONAL TEST
FUNCT TEST PROTOTYPE WITH SEMI-COMPLETE INTERFACE
THERMAL VACUUM TEST
MISSION ENVIRONMENT TEST
COMPONENT LEVEL QUALIFICATION TEST
CLIMATIC TEST
EMI TEST
SHOCK & VIB TEST
ACOUSTIC TEST
THERMAL VAC & HEAT CYCLING
FUNCTIONAL C/O
ABLATIVE THRUST CARTRIDGE ASSY
DEVELOPMENT TESTS
BREADBOARD TEST
FUNCTIONAL TEST
PROTOTYPE
VIBRATION TEST
BLAST & SHOCK EVALUATION OF SIMULATION STRUCTURES
FUNCTIONAL TEST
PRODUCTION MODEL BENCH TEST
THERMAL VACUUM TESTS
BENCH TEST WITH ABLATIVE MATERIAL - HIGH HEAT
COMPONENT LEVEL QUALIFICATION TEST
CLIMATIC TEST
EMI TEST
SHOCK & VIB TEST
THERMAL VAC & HEAT CYCLING
BENCH FIRE
BENCH TEST PTOTOTYPE
BREADBOARD BENCH TEST
FUNCTIONAL C/O BENCH TESTS
DEVELOPMENT TESTS
HELICOPTER DROP TEST BREADBOARD EL CENTRO
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DROP TESTS
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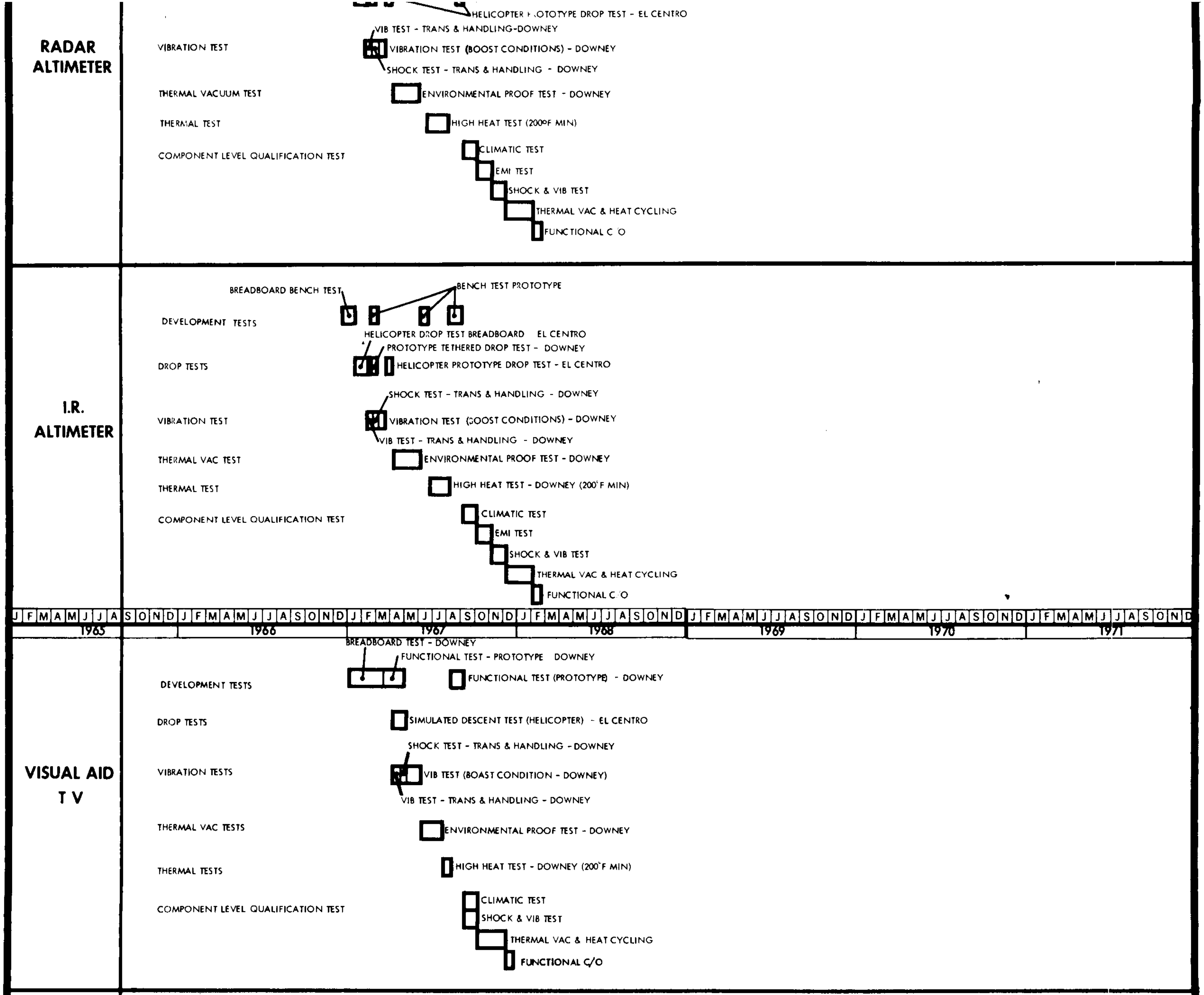

Figure

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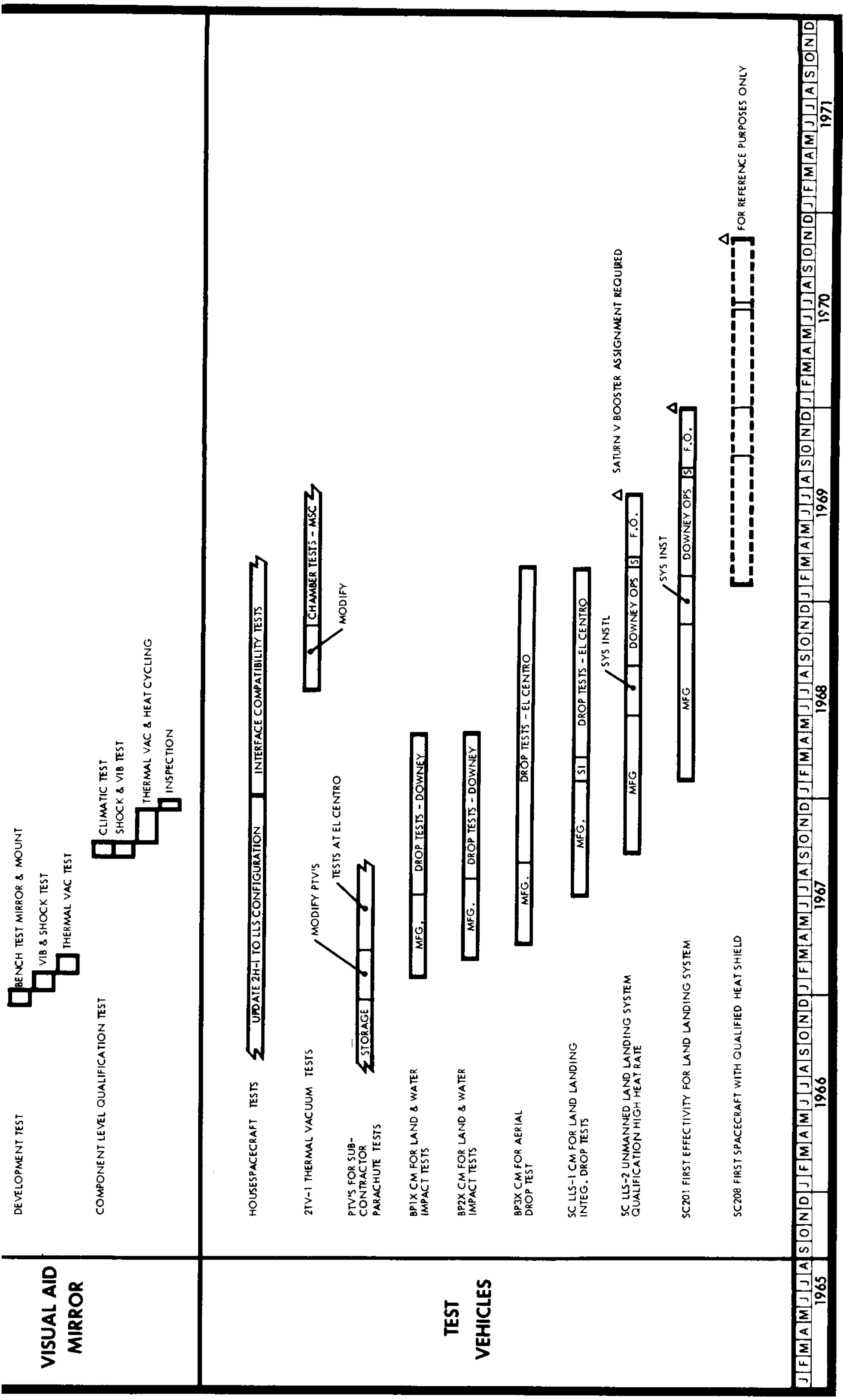

. Integrated Schedule - LLS Configuration II

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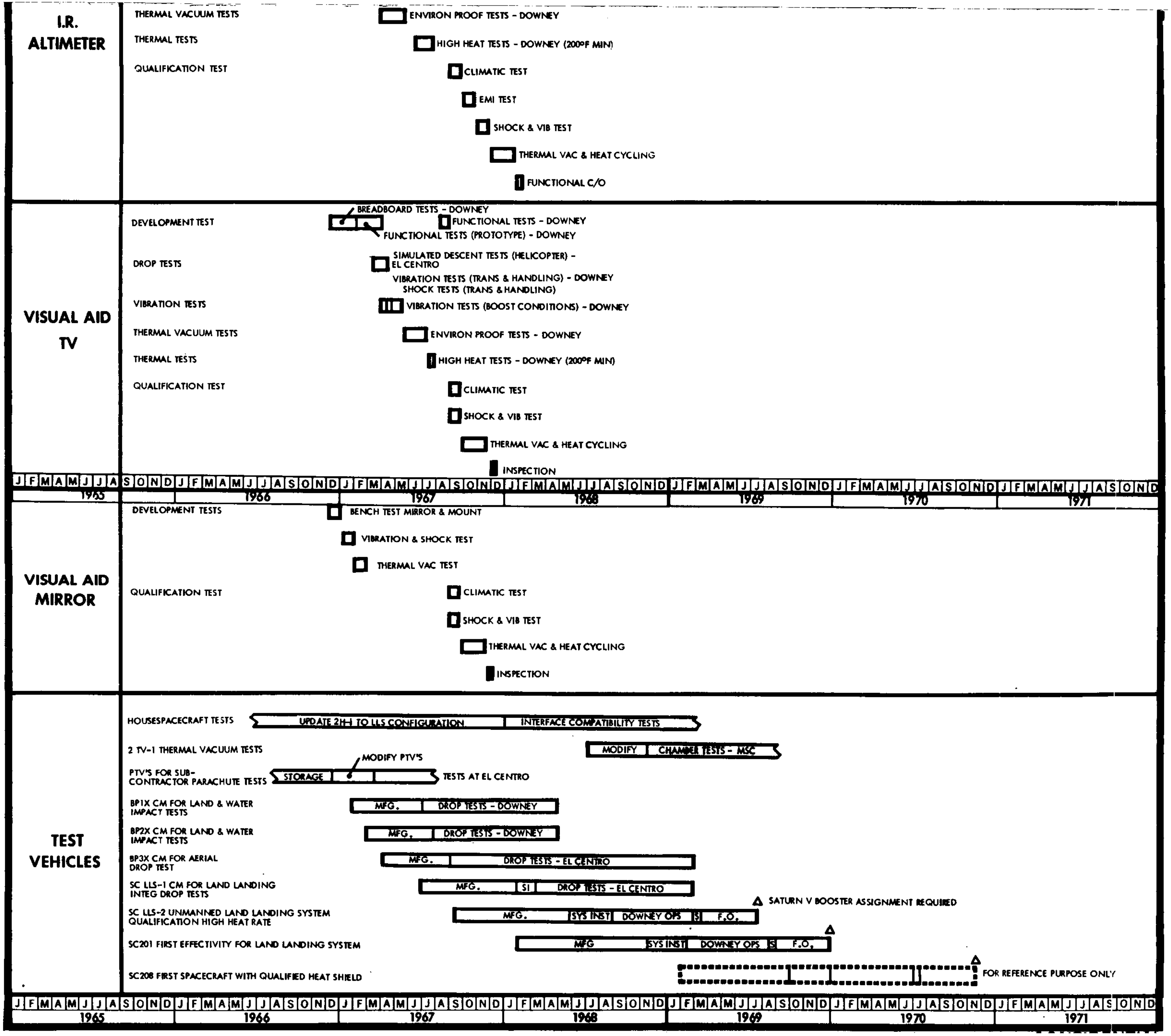

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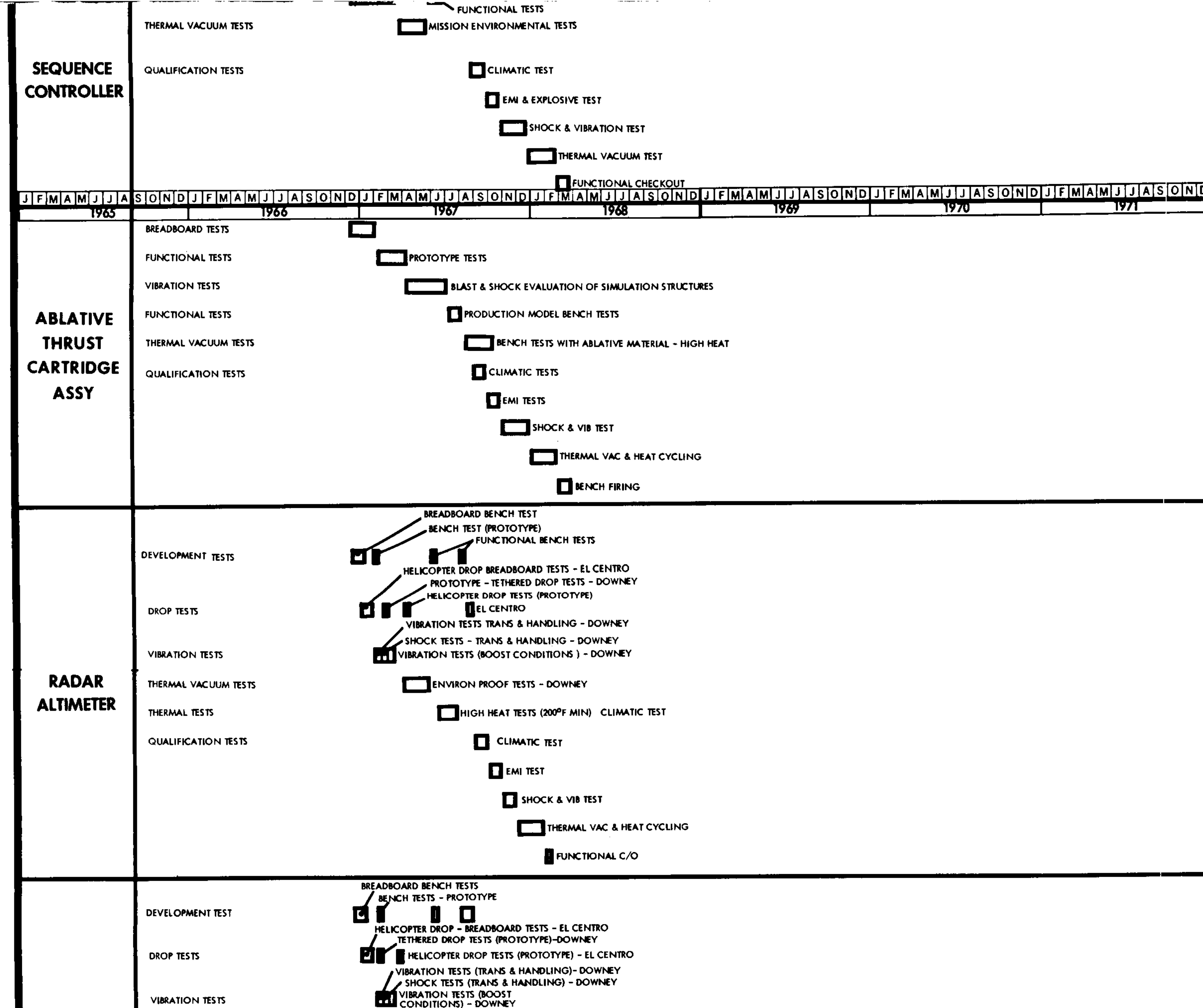

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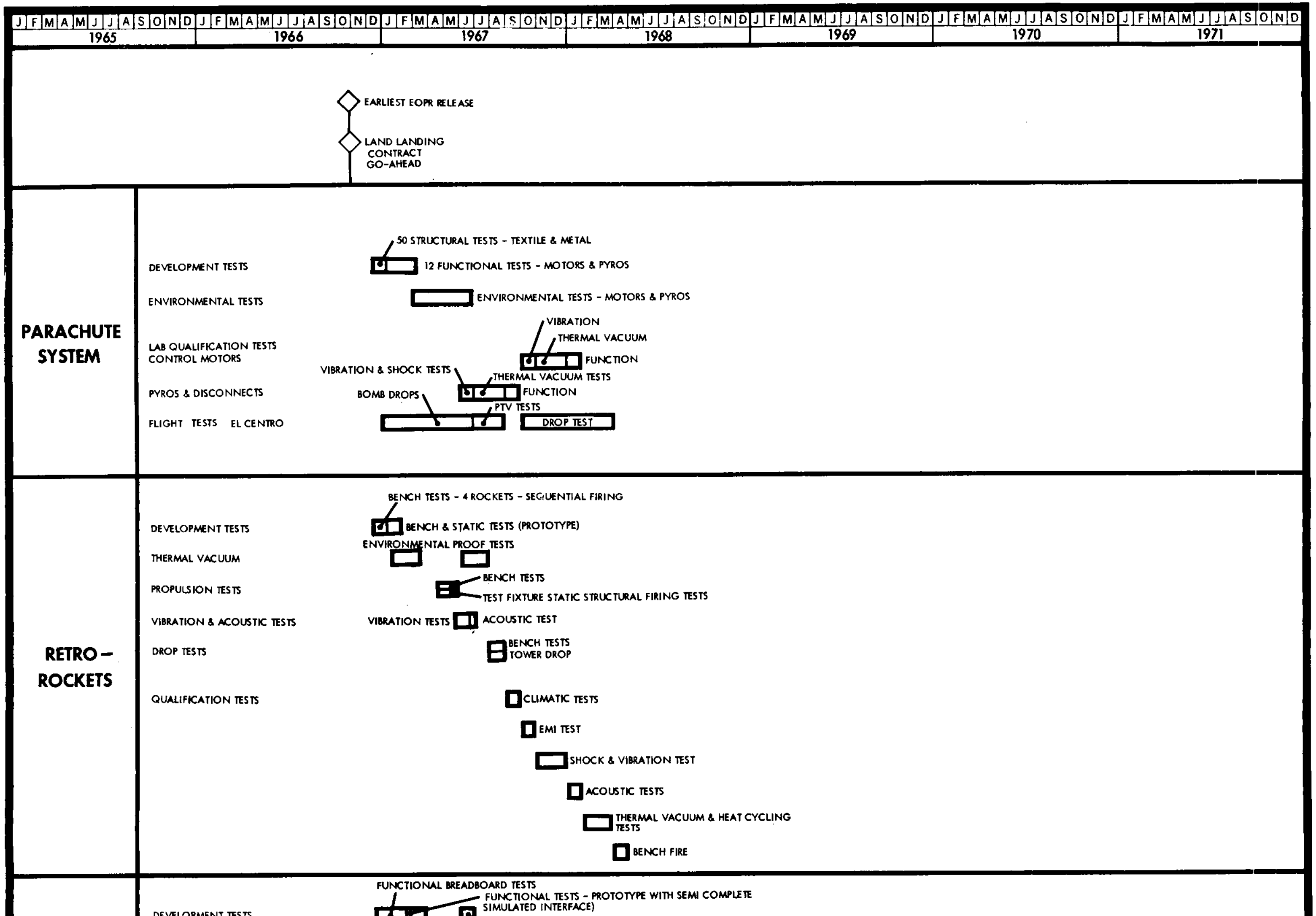

Figure 9. Integrated Schedule - LLS Configuration III

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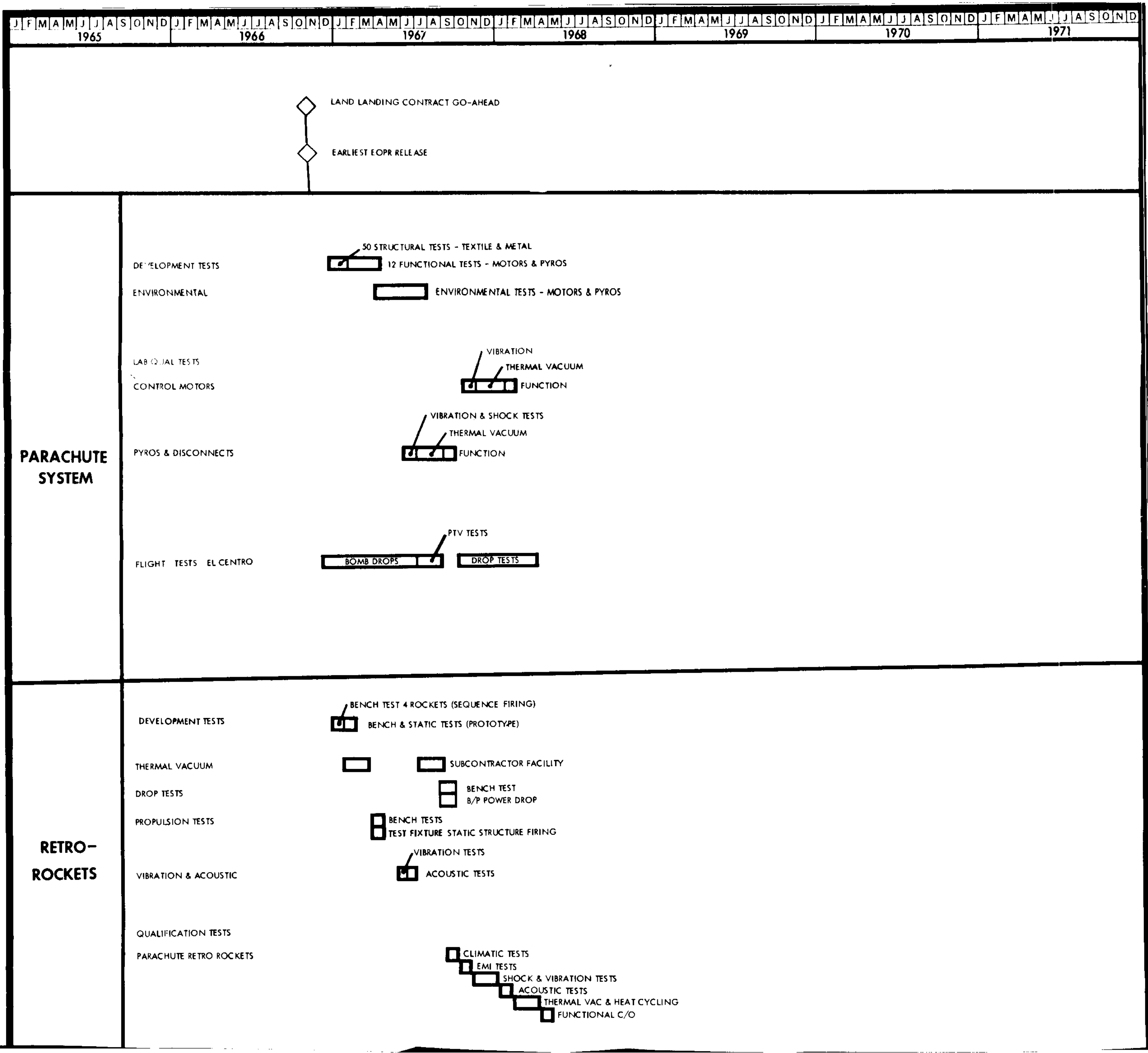
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LAND LANDING CONTRACT GO-AHEAD
EARLIEST EOPR RELEASE
PARACHUTE SYSTEM
DEVELOPMENT TESTS
50 STRUCTURAL TESTS - TEXTILE & METAL
12 FUNCTIONAL TESTS - MOTORS & PYROS
ENVIRONMENTAL
ENVIRONMENTAL TESTS - MOTORS & PYROS
LAB QUAL TESTS
CONTROL MOTORS
VIBRATION
THERMAL VACUUM
FUNCTION
PYROS & DISCONNECTS
VIBRATION & SHOCK TESTS
THERMAL VACUUM
FUNCTION
FLIGHT TESTS EL CENTRO
PTV TESTS
BOMB DROPS
DROP TESTS
RETRO-ROCKETS
DEVELOPMENT TESTS
BENCH TEST 4 ROCKETS (SEQUENCE FIRING)
BENCH & STATIC TESTS (PROTOTYPE)
THERMAL VACUUM
SUBCONTRACTOR FACILITY
DROP TESTS
BENCH TEST
B/P POWER DROP
PROPULSION TESTS
BENCH TESTS
TEST FIXTURE STATIC STRUCTURE FIRING
VIBRATION & ACOUSTIC
VIBRATION TESTS
ACOUSTIC TESTS
QUALIFICATION TESTS
PARACHUTE RETRO ROCKETS
CLIMATIC TESTS
EMI TESTS
SHOCK & VIBRATION TESTS
ACOUSTIC TESTS
THERMAL VAC & HEAT CYCLING
FUNCTIONAL C/O

FOLD-OUT #1

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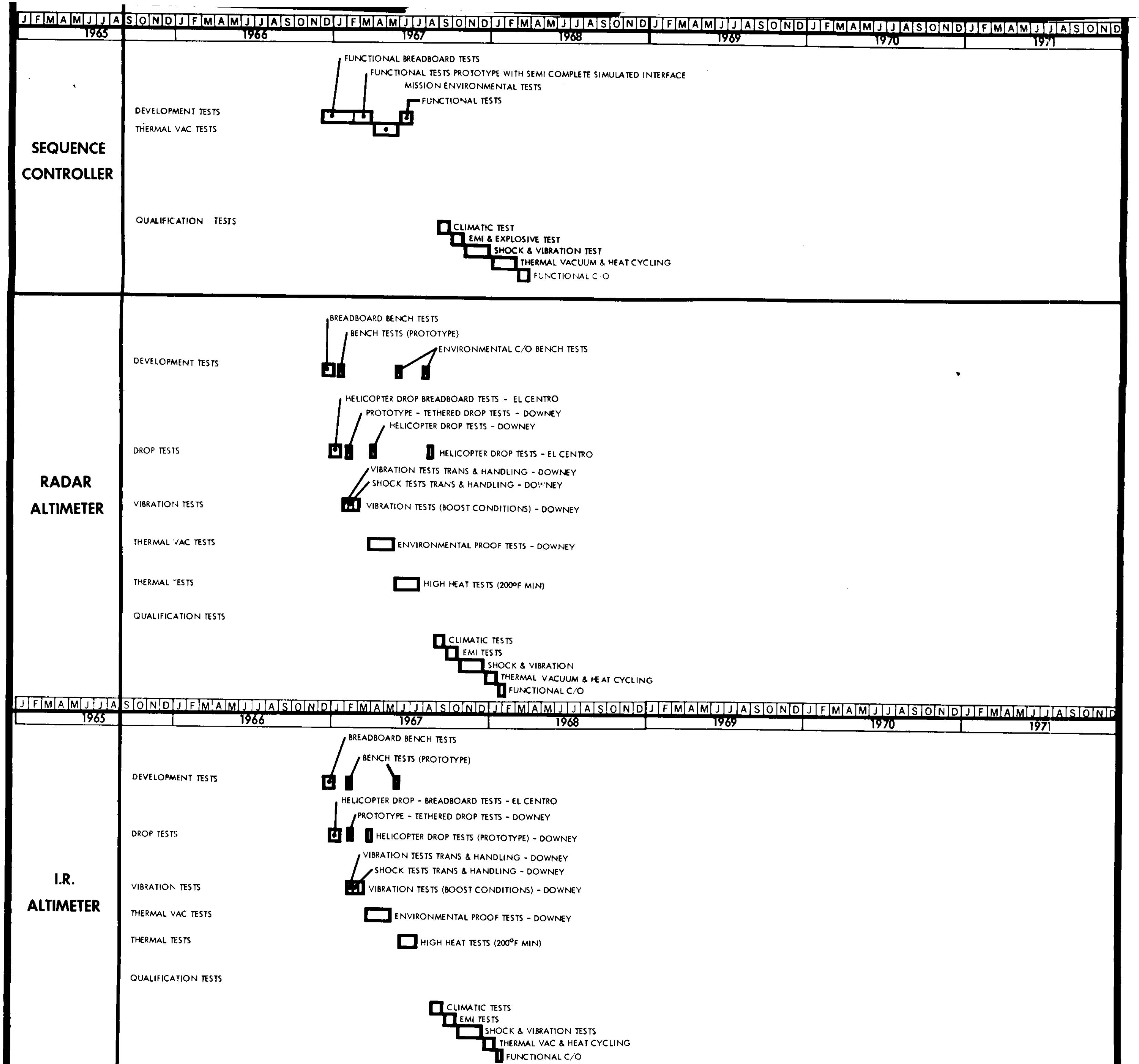

J F M A M J J A S O N D
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1971
SEQUENCE CONTROLLER
DEVELOPMENT TESTS
THERMAL VAC TESTS
FUNCTIONAL BREADBOARD TESTS
FUNCTIONAL TESTS PROTOTYPE WITH SEMI COMPLETE SIMULATED INTERFACE
MISSION ENVIRONMENTAL TESTS
FUNCTIONAL TESTS
QUALIFICATION TESTS
CLIMATIC TEST
EMI & EXPLOSIVE TEST
SHOCK & VIBRATION TEST
THERMAL VACUUM & HEAT CYCLING
FUNCTIONAL C O
RADAR ALTIMETER
DEVELOPMENT TESTS
BREADBOARD BENCH TESTS
BENCH TESTS (PROTOTYPE)
ENVIRONMENTAL C/O BENCH TESTS
DROP TESTS
HELICOPTER DROP BREADBOARD TESTS - EL CENTRO
PROTOTYPE - TETHERED DROP TESTS - DOWNEY
HELICOPTER DROP TESTS - DOWNEY
HELICOPTER DROP TESTS - EL CENTRO
VIBRATION TESTS
VIBRATION TESTS TRANS & HANDLING - DOWNEY
SHOCK TESTS TRANS & HANDLING - DOWNEY
VIBRATION TESTS (BOOST CONDITIONS) - DOWNEY
THERMAL VAC TESTS
ENVIRONMENTAL PROOF TESTS - DOWNEY
THERMAL TESTS
HIGH HEAT TESTS (200°F MIN)
QUALIFICATION TESTS
CLIMATIC TESTS
EMI TESTS
SHOCK & VIBRATION
THERMAL VACUUM & HEAT CYCLING
FUNCTIONAL C/O
I.R. ALTIMETER
DEVELOPMENT TESTS
BREADBOARD BENCH TESTS
BENCH TESTS (PROTOTYPE)
DROP TESTS
HELICOPTER DROP - BREADBOARD TESTS - EL CENTRO
PROTOTYPE - TETHERED DROP TESTS - DOWNEY
HELICOPTER DROP TESTS (PROTOTYPE) - DOWNEY
VIBRATION TESTS
VIBRATION TESTS TRANS & HANDLING - DOWNEY
SHOCK TESTS TRANS & HANDLING - DOWNEY
VIBRATION TESTS (BOOST CONDITIONS) - DOWNEY
THERMAL VAC TESTS
ENVIRONMENTAL PROOF TESTS - DOWNEY
THERMAL TESTS
HIGH HEAT TESTS (200°F MIN)
QUALIFICATION TESTS
CLIMATIC TESTS
EMI TESTS
SHOCK & VIBRATION TESTS
THERMAL VAC & HEAT CYCLING
FUNCTIONAL C/O

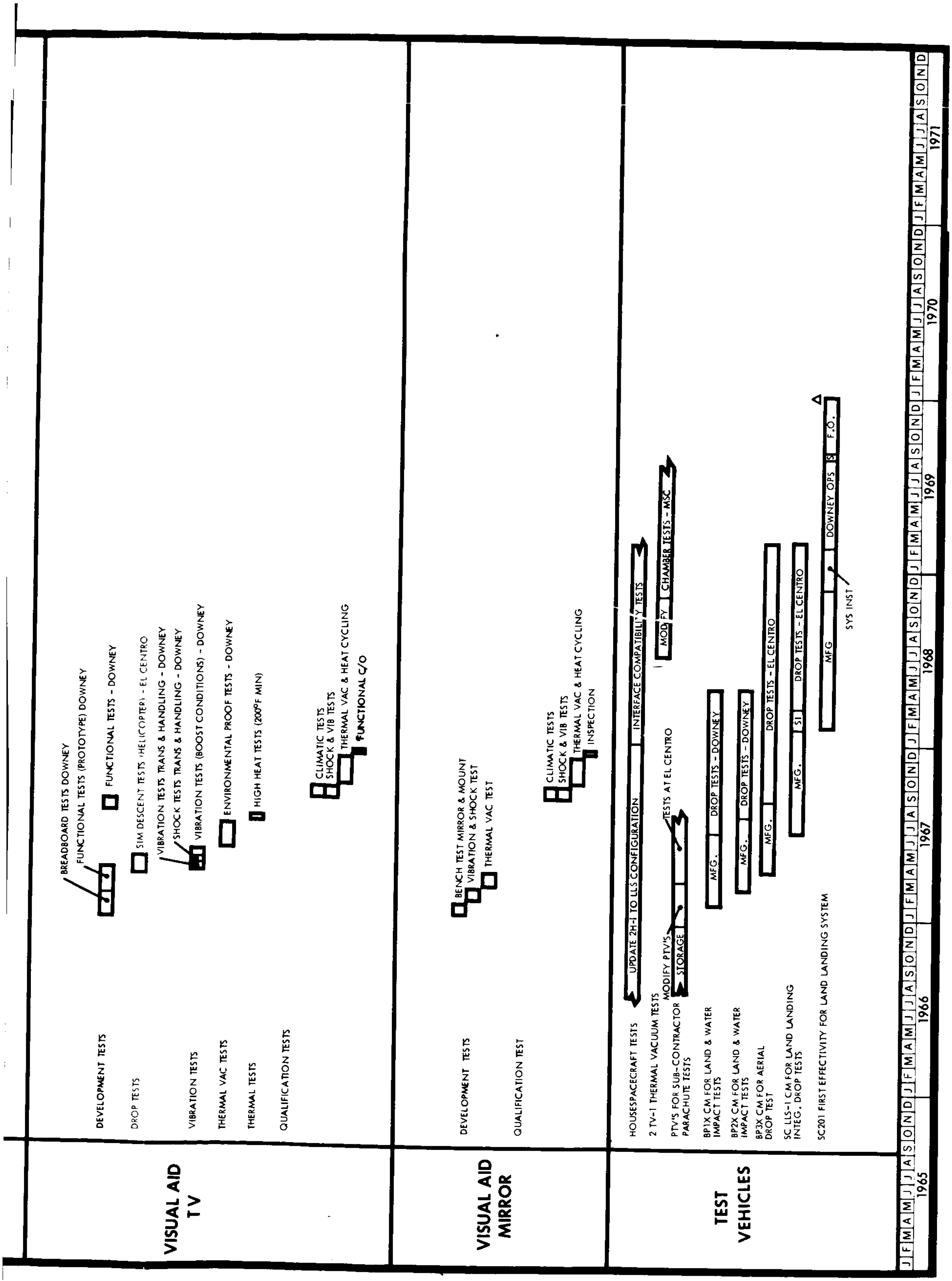

Figure 10. Integrated Schedule - LLS Configuration IV

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The two major elements comprising the LLS Mobile Ground Station are each housed in semi-trailer vans identified as the Telemetry (TM) Van and the Control Van.

The TM Van will be required to support the BP 3X CM drop tests at El Centro. Later, the Control Van will augment the TM Van to support the LLS-1 Integrated drop tests at El Centro. In addition, the LLS-2 vehicle will require full ground station support at its selected landing site.

The Telemetry Van will contain the complete telemetry receiving and data recording equipment. In addition, the transmitting equipment for uplink control of the command module will be in the Telemetry Van.

The Control Van will contain simulated CM LLS controls and displays for use in controlling the command module descent and landing. It will contain all normal CM LLS controls and displays including a TV down link from the CM. A computer will be included to process the LLS TM data and convert it to real time inputs to the LLS displays. It is assumed that electrical power (motor/generator) would be provided as GFE. The LLS Master Schedule (Figure 37) shown the milestone necessary to assure timely development of the MGS.

GROUND SUPPORT EQUIPMENT

GSE requirements have been identified by function rather than by specific end items due to the preliminary nature of subsystem definition. Since GSE requirements are small, all four (4) configurations are presented here.

(Table 1) shows the new and modified GSE required to support the four LLS configurations. Required quantities of each model are also indicated. Following is a brief description of the function of each new model:

1. C34 - XXX - Radar Altimeter c/o set; Used in installed systems tests at Downey, KSC and MSC to verify the altitude and altitude rate functions.

2. C34 - XXY - Radar Altimeter BME; Provides bench check capability of the altimeter units at Downey, KSC and MSC.

3. C34 - YYY - IR Altimeter c/o set - used in installed systems tests at Downey, KSC and MSC to verify the altitude and altitude functions.

4. C34 - YYX - IR Altimeter BME - Provides bench check capability of the altimeter units at Downey, KSC and MSC.

5. C34 - XYY - ERS TV display c/o set - used in installed systems tests at Downey, KSC and MSC to verify TV display resolution sensitivity and the drift meter function.

6. C34 - ZYY - ERS TV display BME - Provides bench check capability of the TV display units at Downey, KSC and MSC.

7. C34 - ZZZ - ERS Flight Control System c/o set - Used at Downey, KSC and MSC to check control reel rates and cable travel on an end-to-end system basis.

8. C34 - ZZY - ERS Flight Control System BME - Provides bench check capability of the system units at Downey, KSC and MSC.

Since configuration I requires the least amount of GSE, it is the most desirable from a GSE development standpoint. Differences in GSE requirements for Configurations II, III and IV are not great enough to become a significant configuration selection factor. From a Ground Operations standpoint, Configuration IV offers the advantage of greater accessibility to sensors and retro-rockets during prelaunch checkout.

[redacted]

Table 1. Land Landing System GSE

Model	Name	Qty./ Config.	Appl. Config. and Mod. I	II	III	IV
	<u>NEW GSE</u>					
C34-XXX	Radar Altimeter C/O Set	4		X	X	X
C34-XXY	Radar Altimeter BME	3		X	X	X
C34-YYY	IR Altimeter C/O Set	4		X	X	X
C34-YYX	IR Altimeter BME	3		X	X	X
C34-XYY	ERS TV Display C/O Set	4		X	X	X
C34-ZYY	ERS TV Display BME	3		X	X	X
C34-ZZZ	ERS Flight Control System C/O Set	3			X	X
C34-ZZY	ERS Flight Control System BME	3			X	X
	<u>MODIFIED GSE</u>					
H14-044	Parachute Handling Sling	4		+15%	+15%	+15%
C14-451	ELS Sequencer Cont. Press. Generator	4		+10%	+10%	+10%
C14-452	ELS Control Electrical Test Stand	4	+5%	+20%	+20%	+20%

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MANUFACTURING

Manufacturing analyses for incorporation of the Land Landing System into the basic AES command module configuration (Figure 11) were carried out in general compliance with the basic manufacturing program as defined in the AES Preliminary Manufacturing Plan, SID 65-1146.

Analyses and evaluation of the land landing concepts have determined that the inclusion of any one of the four land landing configurations into the AES spacecraft would present no major impact to manufacturing. Analyses performed during the study include:

> Identification of those areas of the Command Module which would require modification to accept each Land Landing System concept.
>
> Determination of scope of modification required on the Command Module to accommodate each Land Landing System concept.
>
> Identification of those areas of the installation sequence which may be affected by the Command Module modification initiated to accommodate each Land Landing System concept.
>
> Establishment of schedule factors which would illustrate typical lead times required to implement manufacturing structural fabrication and system installation and test for each LLS concept.

Those elements of the command module requiring modification to accept installation of each land landing system concept are identified and the extent of modification estimated and discussed in subsequent paragraphs of this section. The baseline for the manufacturing analysis is that shown in Figures 2, 3, 4, 5 and 6.

The structural and systems modification requirements for each land landing system configuration are dissimilar and are discussed separately.

Manufacturing assembly and tooling modification requirements to incorporate each of the landing system configurations in the basic AES spacecraft are also discussed for each configuration.

The four candidate configurations, were reviewed for schedule impact on the AES program. Consideration is given for in-line incorporation of an approved configuration on the first AES flight vehicle thereby optimizing spacecraft design and existing Manufacturing techniques and processes.

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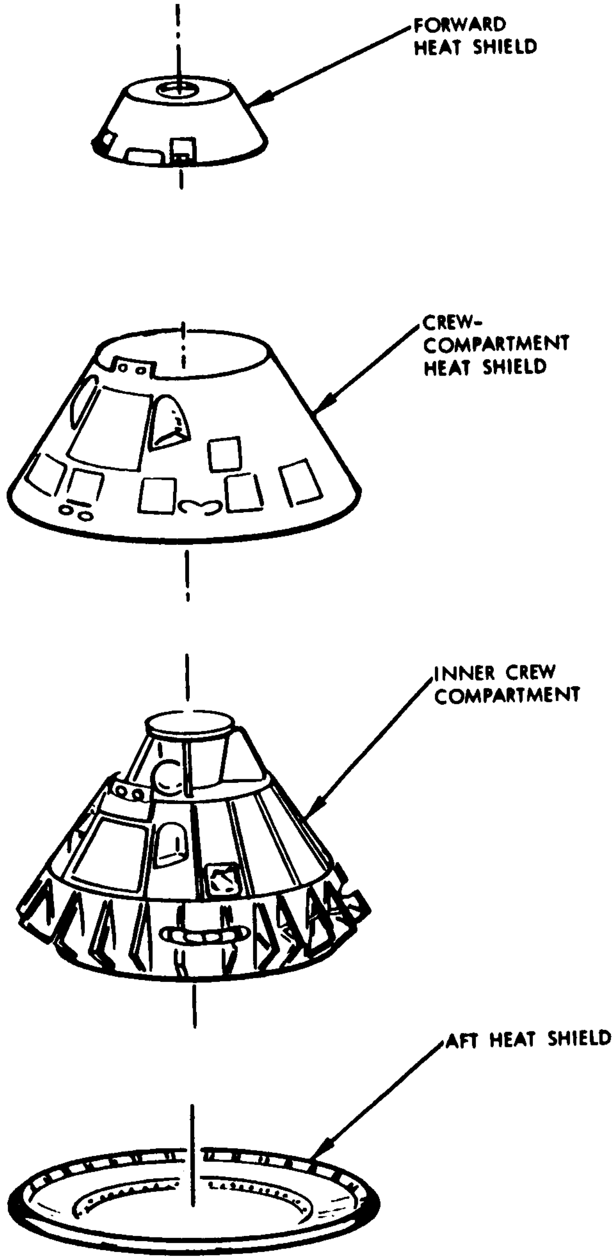

Figure 11. Block II/AES Command Module Breakdown

The Manufacturing time spans for command module assembly fabrication, systems installation, and checkout are in consonance with AES Master Development Schedule 11-2 (Figure 36). Fabrication and systems installation sequences will be maintained as planned for AES and as previously developed for the Apollo Block II program.

CONFIGURATION I

The necessary structural fabrication and assembly changes and dimensional tooling modifications required to incorporate Configuration I into the spacecraft are as follows:

COMMAND MODULE STRUCTURE

The basic configuration of the command module inner structure will remain essentially the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for certain structural revisions required for installation of Land Landing Subsystem, Configuration I.

INNER CREW COMPARTMENT

The inner crew compartment forward equipment area (Figure 12) will be revised to accept a newly configured structural mounting frame for the installation of a modified parachute structure support assembly. The changes necessary are:

1. The exterior attachment members bonded on the access cylinder sidewall will be relocated to accept the new frame. This will necessitate a revision to the bonding jig and coordinating master tooling, including master control simulator and tool master.

2. The forward bulkhead outer face sheet will require a modified chem-mill land area, in conjunction with the new frame. This will have a minimal effect on manufacturing.

The inner crew compartment aft sidewall (Figures 13 and 14) will be revised to accommodate the installation of two new retro-rocket structure support assemblies located in the aft compartment area between Frames #1 and #2 and Frames #11 and #12. The necessary changes are:

1. The aft sidewall inner skin weld assembly will be revised in the areas of Frames #1 and #2 and Frames #11 and #12, by incorporating four machined fittings to permit installation of the retro-rocket structure support assemblies. This assembly change will require the rework of two major weld jigs, coordinating master model and a tool master to control location of the fittings.

2. The aft sidewall primary bond assembly will be modified to accept the new machined fittings at 4 places in the inner skin weld

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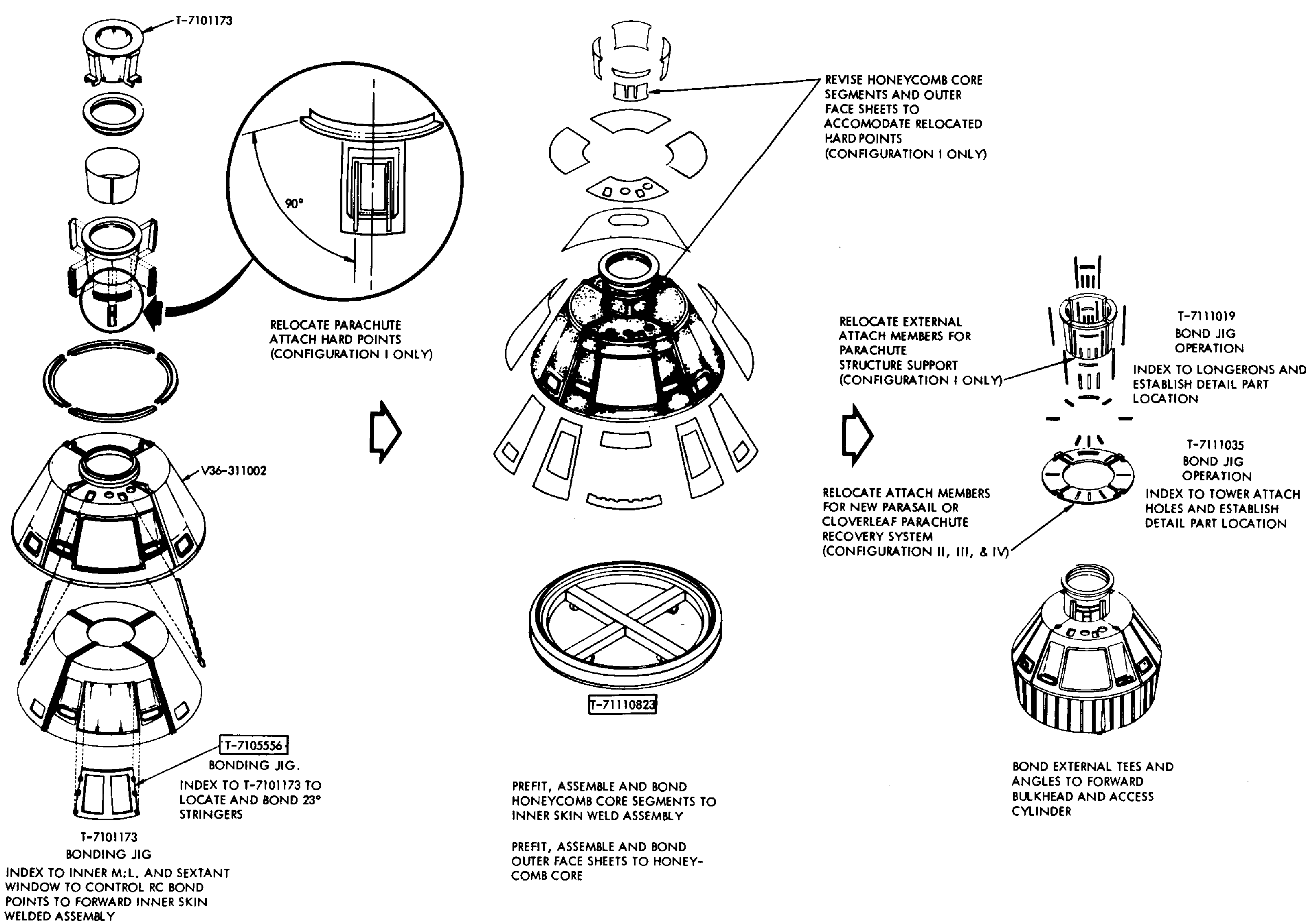

Figure 12. AES Inner Crew Compartment Forward Bond Assembly

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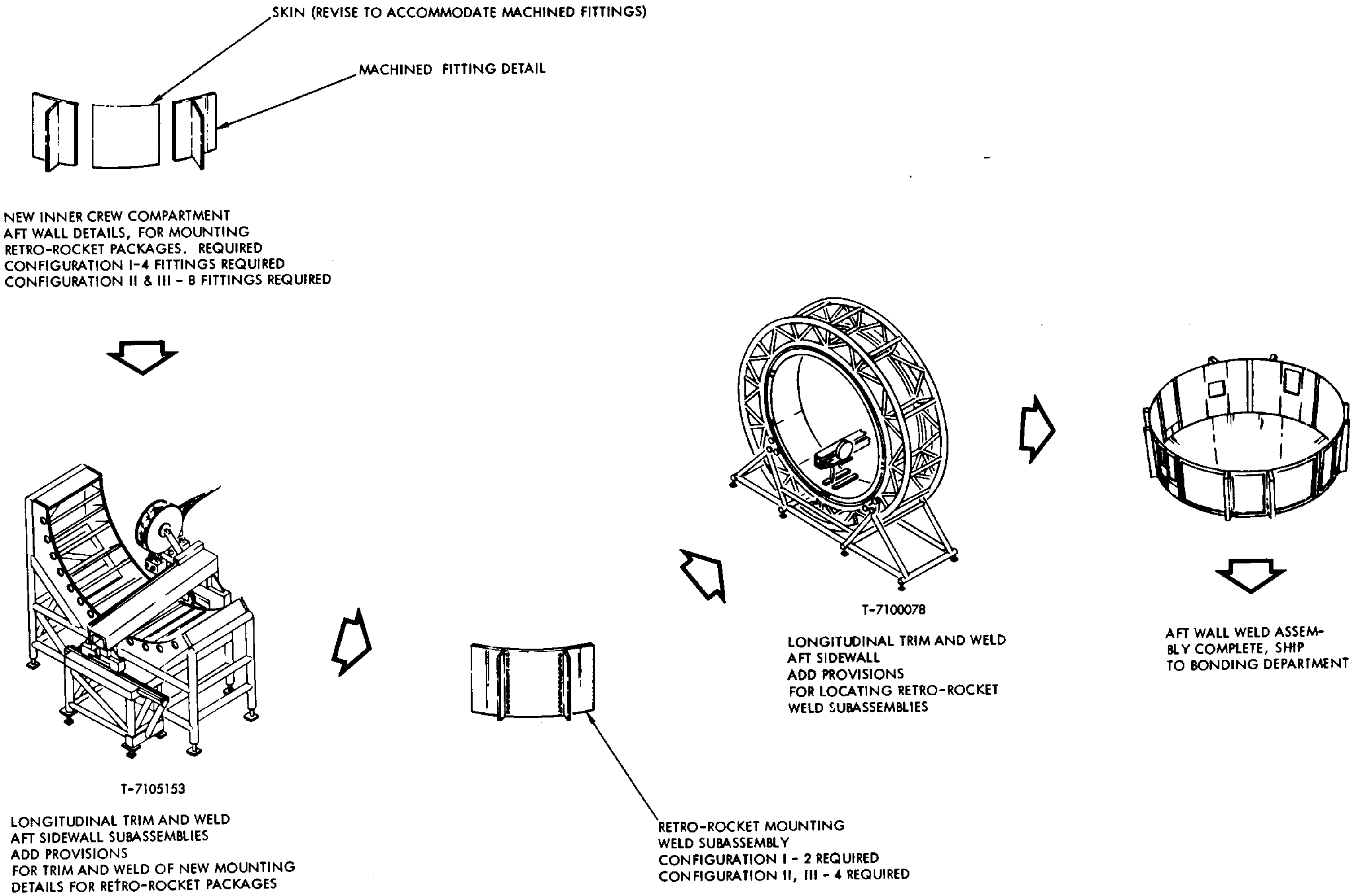

Figure 13. AES Inner Crew Compartment Structure Weld Assembly

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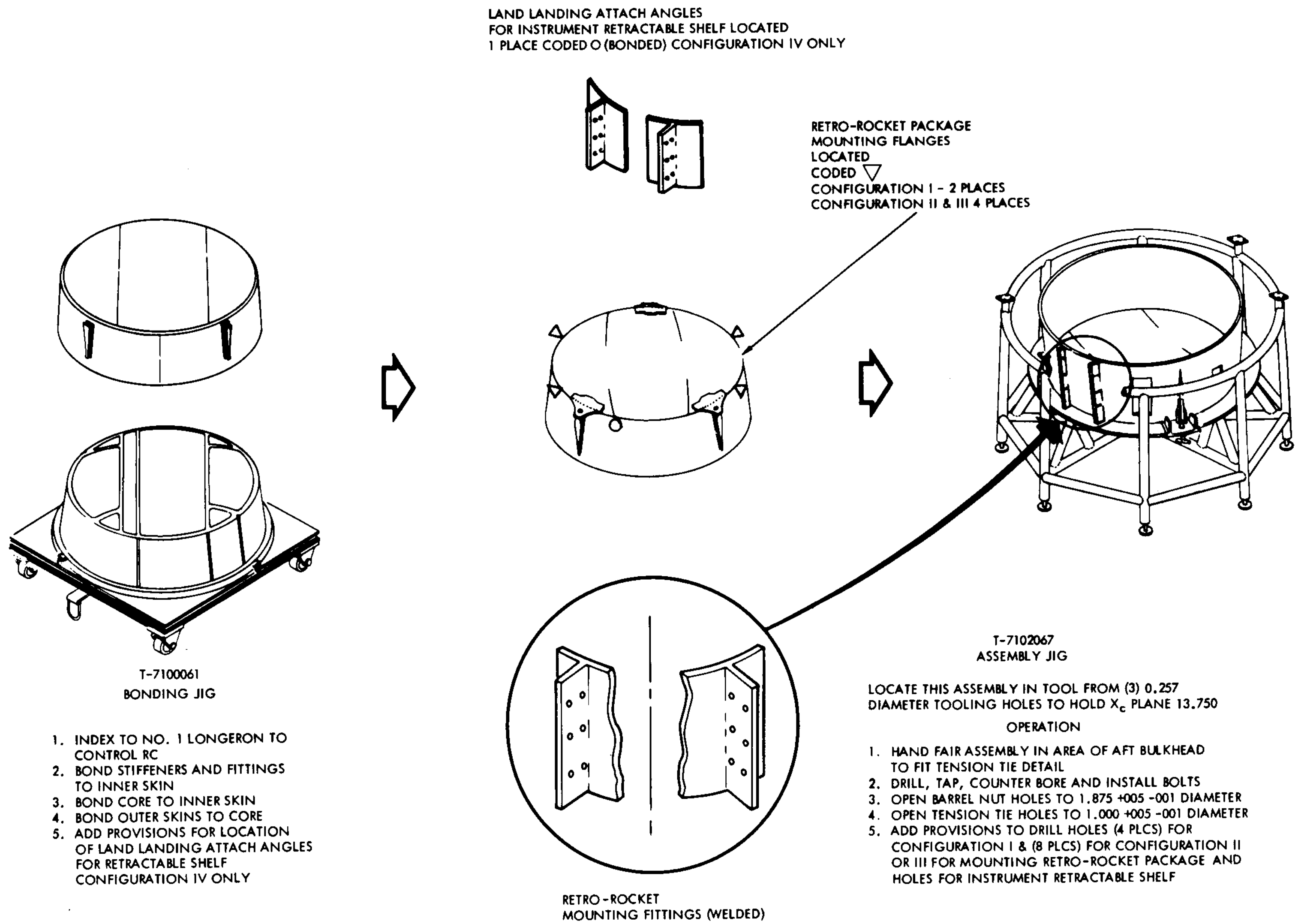

Figure 14. AES Inner Crew Compartment Aft Bond Assembly

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assembly. This will necessitate a rework of one major bond jig.

The inner crew compartment sidewall will be revised by adding structural support for installation of a small mirror in the area of the left and right hand side windows. This addition will require fabrication of the structure supports and minimal installation time to install the structure supports onto the inner crew compartment. No basic tooling effort will be necessary.

SYSTEMS SUPPORT STRUCTURE

The parachute support structure located in the command module forward equipment compartment, -Z quadrant, will be revised to accommodate a "controllable swivel" drogue and main chute disconnect assembly (Figure 15). The changes necessary for incorporating this provision are:

1. A new drogue and main chute disconnect "flower-pot" assembly will be required. This assembly will consist of a hand forged titanium housing containing a motor actuated swivel, motor and gear box with worm gear drive, drogue, and cable cutters. This will be a purchased assembly.

2. A family of master tools will be necessary to coordinate this assembly with the parachute support structure, including a control master, a tool master, a tool master supplied to the vendor and a tool master for S&ID use.

3. The present parachute attach structure will be a modified machined aluminum frame assembly which attaches to the command module access cylinder sidewall, forward bulkhead, and two thruster assemblies. A new major special tool will be required to locate the structure fitting and hold it in proper relationship to the inner crew compartment for drilling all attach holes for mechanical installation, and in-line and parallel holes for installation of the disconnect "flower-pot" assembly.

4. Master tool support will be required to maintain close tolerance, dimensional control of the parachute riser confluence point. This change will not impact fabrication, assembly, or installation operations.

The command module aft compartment area (Figure 16) will be extensively revised in order to support the installation of the retro-rocket motors and the ground sensing subsystems. The necessary changes are:

1. Revision of Frames #1, #2, #11, and #12 will be required to provide for the installation of the landing rocket assemblies. Frames #19 and #20 will be modified to support installation of a relocated helium tank and uprighting system compressor. Frames #23 and #24 will be revised to provide for a relocated RCS motor switch assembly. These frame changes will include provisions for rerouting of the electrical wire bundles. This change will not impact fabrication,

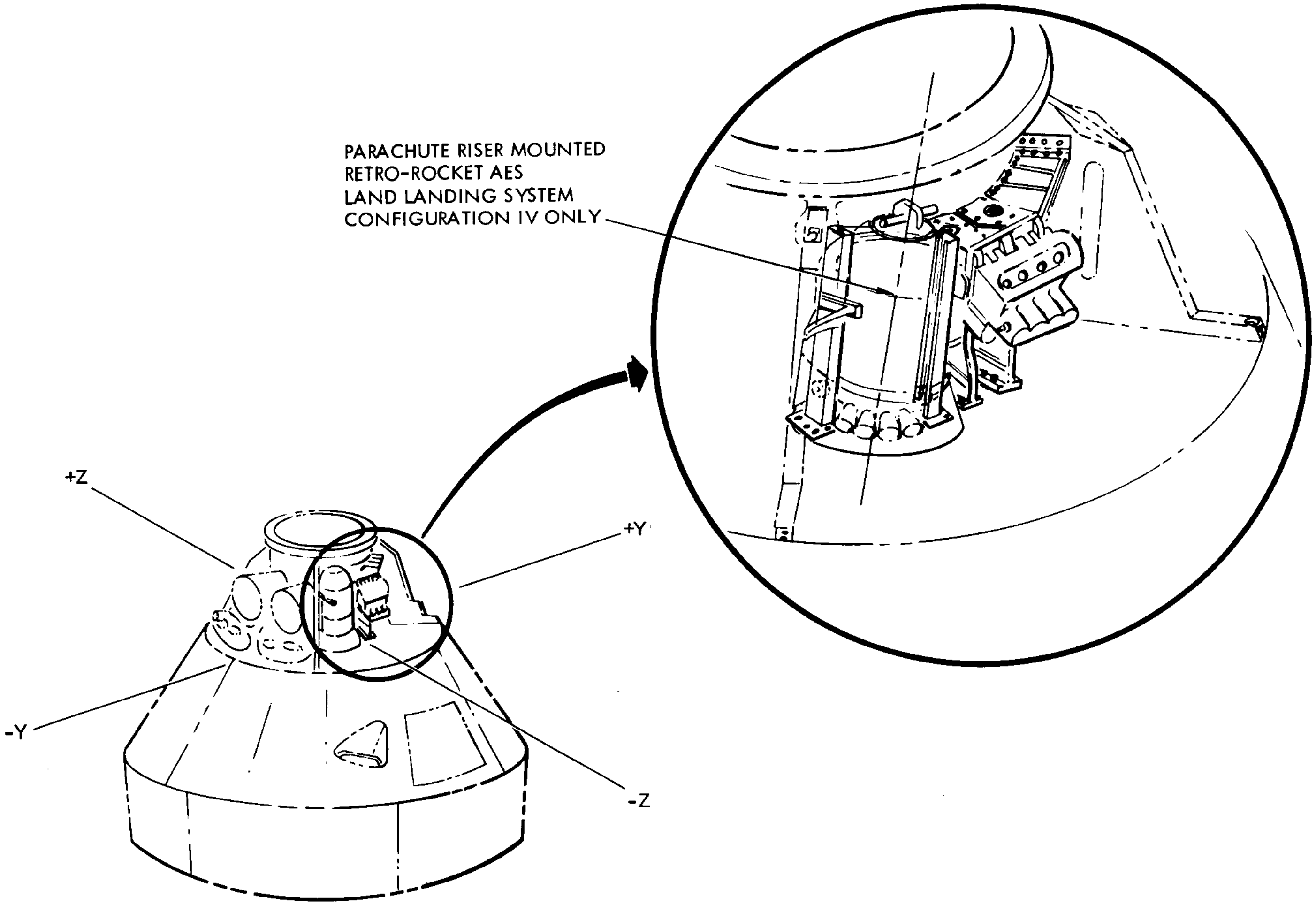

Figure 15. AES Command Module Forward Equipment Compartment Parachute Structure

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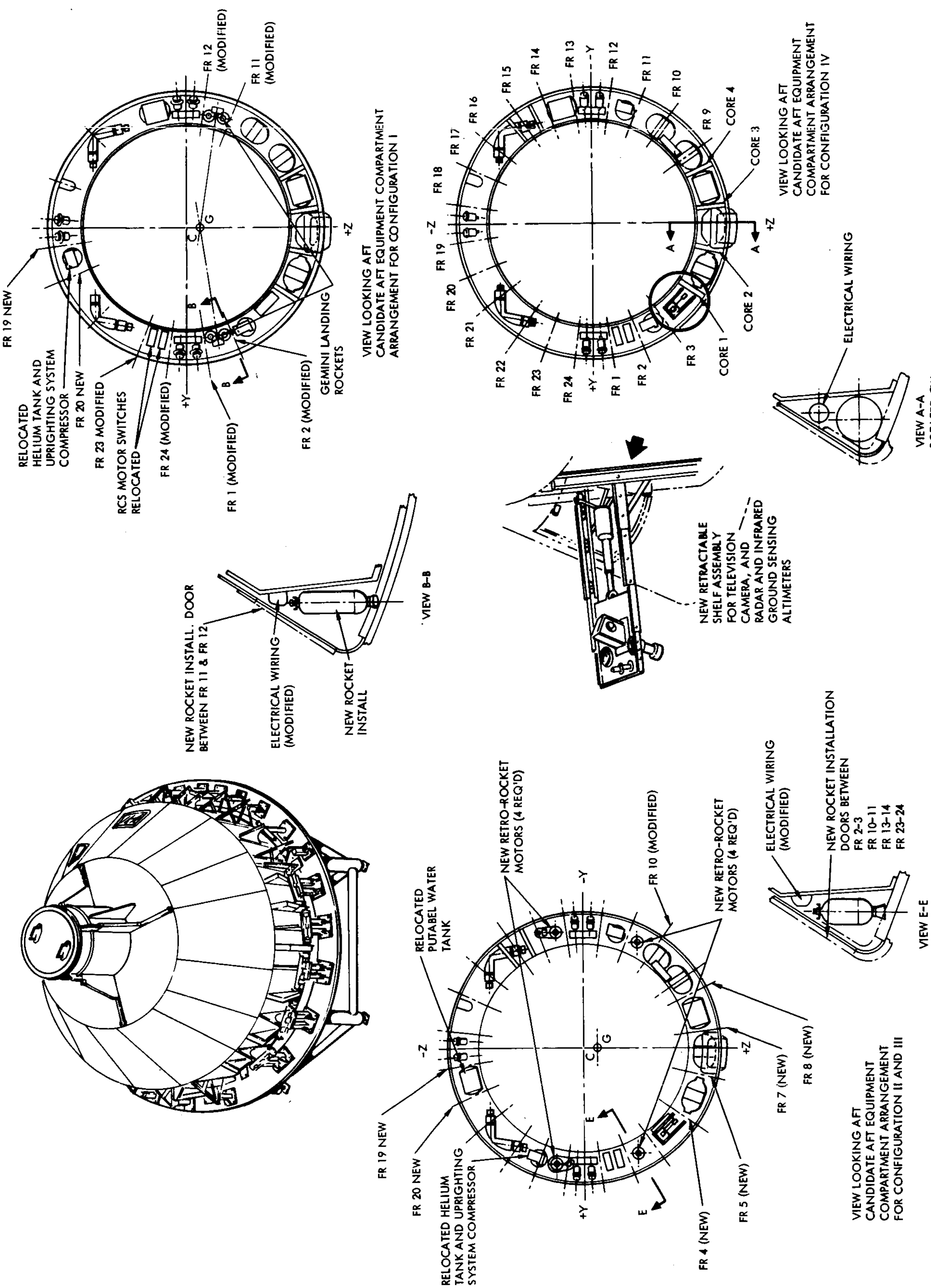

Figure 16. AES Command Module Aft Compartment Arrangement

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assembly, or installation. Basic tooling changes will be minimal.

2. Installation of the retro-rocket motors and the ground sensing probes will require two support structure assemblies. Left and right hand assembly jigs will be required to assemble the support assemblies prior to installation on the inner crew compartment. A family of tooling masters will be needed to control interchangeable attach provisions between the purchased retro-rocket assemblies; the ground sensor probe assembly and the structure support assembly. Tool masters will be furnished vendors by S&ID to ensure this control. Drill jigs will be necessary for drilling attach holes in the inner crew compartment aft sidewall attach fittings. Fabrication of the support structure will increase fabrication, assembly and installation operations.

HEAT SHIELD

The basic configuration of the heat shield will remain the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for access panel doors and exhause openings being added to support the retro-rocket motor assembly installation. These revisions are discussed in the following paragraphs.

<u>Crew Compartment Heat Shield</u>

The crew compartment heat shield aft section (Figure 17) will include major revision for incorporation of two new access panel doors. These doors, between Frames #11 and #12 and between #23 and #24, provide accessibility to the relocated RCS motor switch assembly, and to one of the retro-rocket motor assemblies. The existing access panel door between Frames #1 and #2 will be modified to provide accessibility to the other retro-rocket motor assembly. These new and modified access panel doors will require major modification to the honeycomb panel assemblies adjacent to the doors. The fabrication and assembly requirements will be increased to fabricate the two new access panel doors. Basic assembly tools for the aft crew compartment heat shield, including supporting master tools (master models, tool masters, etc.), will require extensive rework.

<u>Aft Heat Shield</u>

The aft heat shield (Figure 18) will be modified to incorporate two retro-rocket exhaust and ground sensor probe openings to support the land landing rocket systems located in the aft equipment bay. The following changes are necessary:

1. The aft heat shield honeycomb panel assembly will be modified to include two cutouts to accept machined cup fittings. The areas in which the cutouts are located will require structural reinforcement to allow for attachment of the fittings and the thruster mechanism for ejecting the ablative plug. Assembly and

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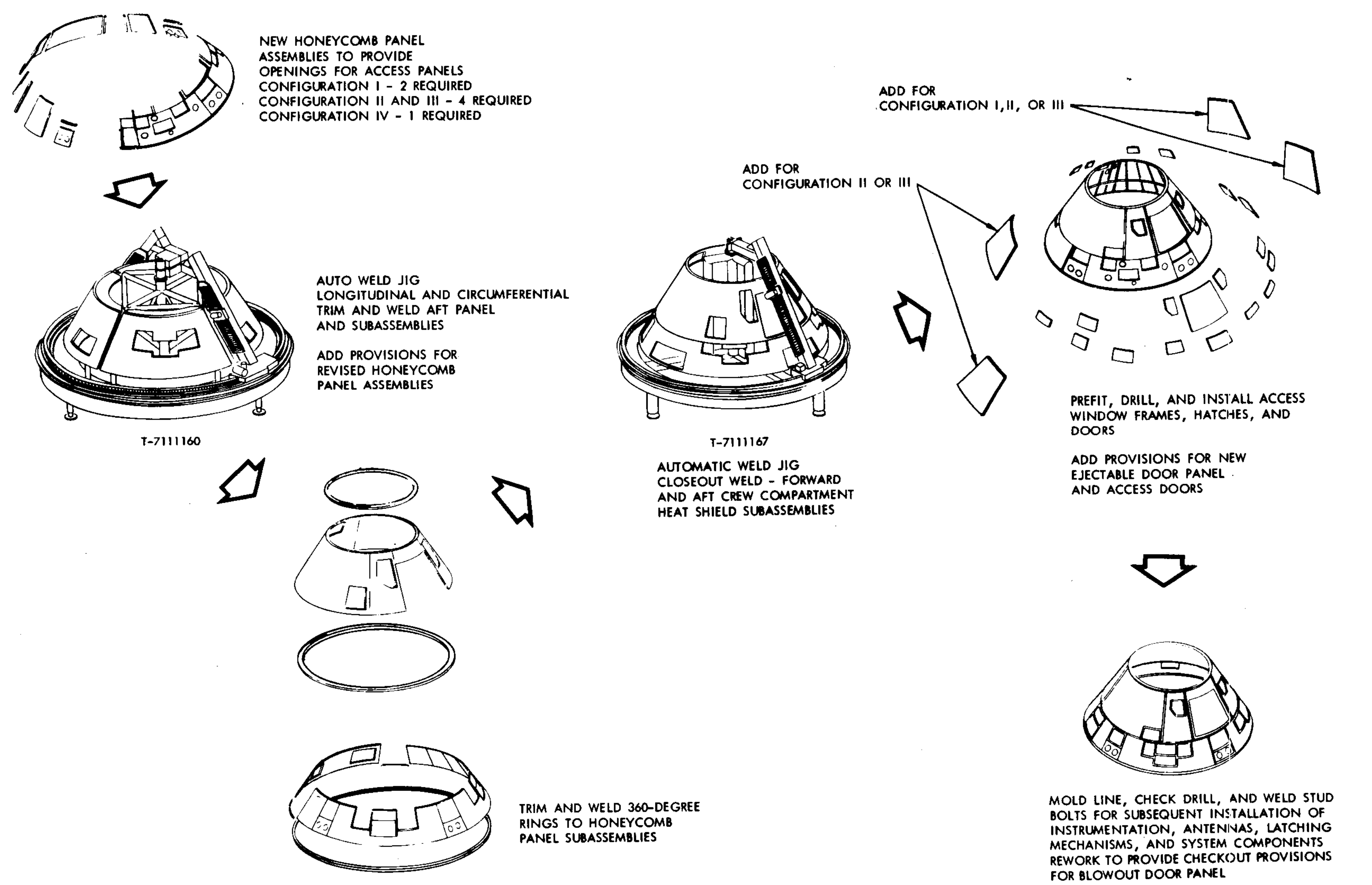

Figure 17. AES Crew Compartment Heat Shield Structure Assembly

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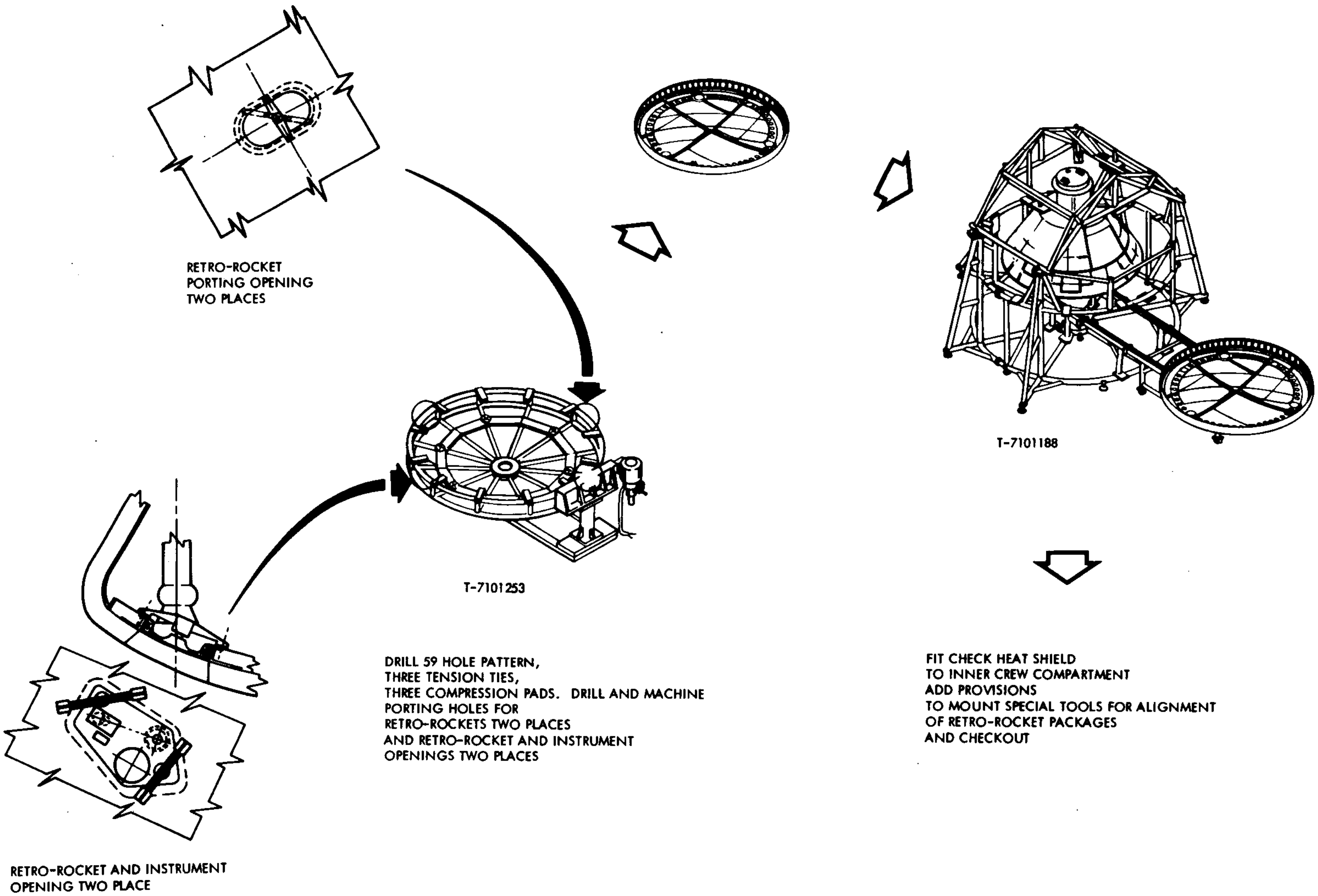

Figure 18. AES Aft Heat Shield Assembly

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installation operations will be increased to make the cutouts and install the cup fittings and thruster mechanism. A major assembly drill jig will be reworked to make the cutouts and must be mastered by control tools to assure proper cutout locations.

2. A retro-rocket exhaust plug machined fitting will be fabricated to provide for the retro-rocket exhaust nozzles, the ground sensor probes, and the thruster mechanism. No basic tooling support is required.

3. An ablative plug will be added in the outer ablative installation in conjunction with the exhaust plug fitting. This change will be accomplished by a subcontractor.

4. Two cartridge thruster assemblies will be fabricated and installed on the aft heat shield to eject the ablative plugs prior to ground sensor deployment and final landing operations. No additional basic tooling requirements will be needed.

INSTALLATION ANALYSIS

Installation of the swivel mechanism requires additional wire harnesses to supply power to the actuation motor, and swivel position readout on the display panel. Wiring will also be required for the actuation of the ablative plug jettison thruster, relays, sequencer, deployment of the sensor probes, and the firing of the retro-rockets. It is estimated that new wires and connectors will be added to accommodate these changes.

Based on the use of solid propellant charges for the heat shield ablative plug jettison, and for the retro-rockets, no new plumbing would be required. Relocation of the existing components to accommodate the new arrangement in the aft compartment area will affect the flotation system compressor, helium tank, the electrical subsystem, and the reaction control subsystem motor switches. This will require mock-up and fabrication of new tubing details for the flotation system and helium tank; mock-up of the electrical wire harness; and modification of the reaction control system (RCS) switch wiring. The RCS panel space, by selective switching, will also be utilized for the parachute swivel mechanism actuation and readout.

The addition of a small mirror to provide visibility from each command module side window will result in a minor installation.

Simulators will be used in all installations that require explosive charges or rockets to interface with electrical harness connectors.

MANUFACTURING SCHEDULE ANALYSIS

Schedule consideration for Configuration I will be; the utilization of four Gemini retro-rockets installed in two locations in the aft equipment compartment; a ground sensing system consisting of two extendable probes also located in the aft equipment compartment; and a revision to the present Apollo

[redacted]

earth recovery system for incorporation of a controllable swivel with single point suspension.

The Manufacturing areas affected are shown in Figure 19. As indicated, subassembly of the aft sidewall will be affected as well as the bonding of the aft sidewall and access cylinder hardpoints, necessary for incorporating the parachute swivel. The controllable swivel design will result in long lead time procurement of investment castings which will require early releases to support a lead time of approximately 40 weeks. The aft heat shield will be affected as a result of the necessity for revision of the Aeronca heat shield panels to accomplish weight reduction, and also to incorporate penetrations for the two retro-rocket exhaust and ground sensor probe openings.

The aft crew compartment heat shield will require schedule consideration for incorporation of two new access panel doors to provide accessibility to retro-rocket motor assemblies. Mechanical systems, plumbing installation, and electrical installation will be affected by this configuration, but will have minimum impact on manufacturing schedules. The display console and control panels will not be affected by the direct vision made for this configuration.

Additional schedule considerations will be necessary to support the extensive tool modification which will be required by Manufacturing to incorporate this configuration. Master tools, assembly weld and bond fixtures, and detail tools will be affected in subassembly, assembly, and secondary structure. Adequate tool rework turn-around time will be required in order to accomplish timely incorporation of modifications with minimum impact to Manufacturing schedules.

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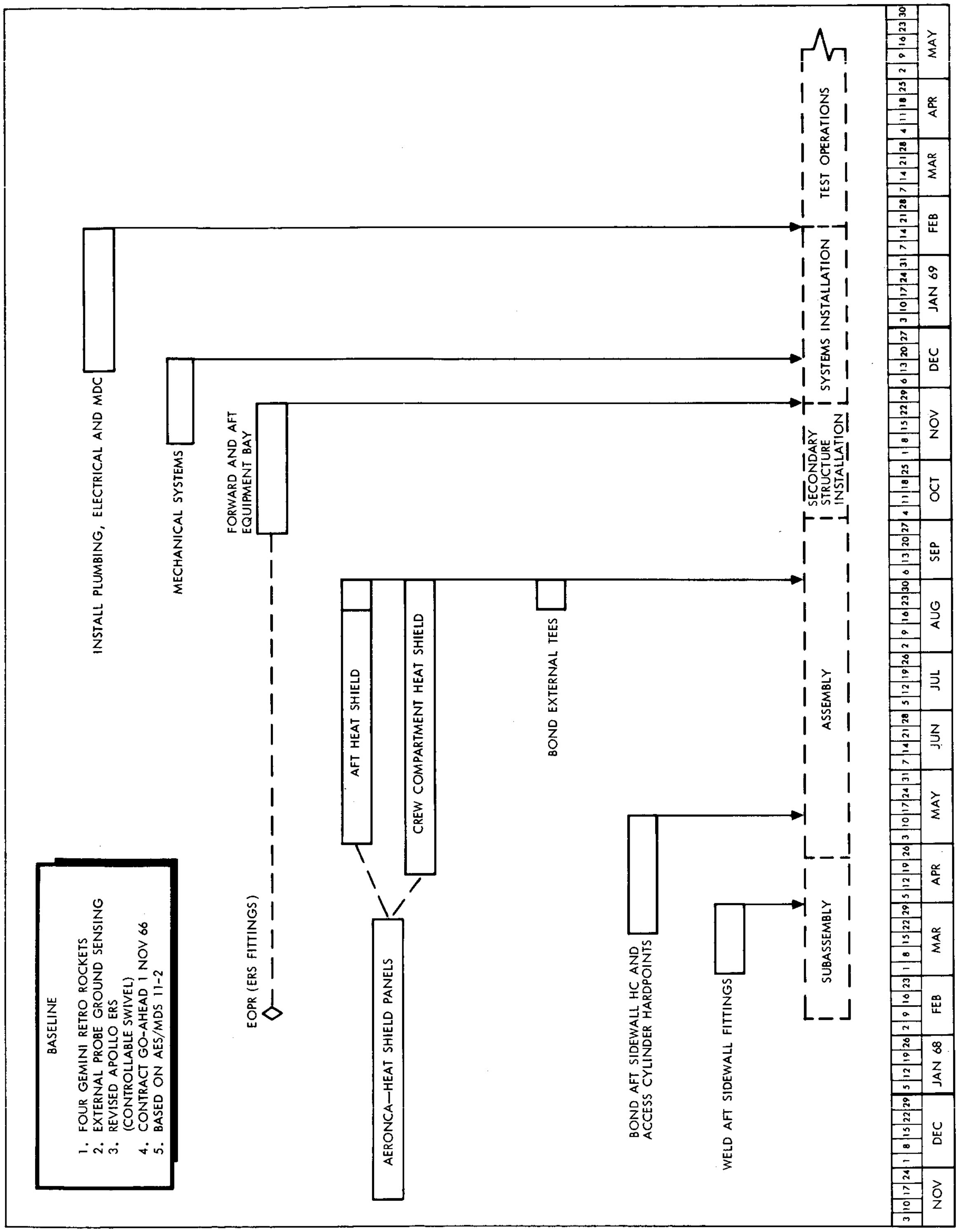

Figure 19. AES/LLS Configuration I Manufacturing Schedule

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CONFIGURATION II

The necessary structural fabrication and assembly changes and tooling modifications required to incorporate Configuration II into the spacecraft are as follows:

COMMAND MODULE INNER STRUCTURE

The basic configuration of the command module inner structure will remain essentially the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for certain structural revisions to provide for installation of the Configuration II Land Landing Subsystem.

INNER CREW COMPARTMENT

The inner crew compartment forward equipment area (Figure 12) will be revised to accept a Parasail steerable parachute recovery system with a primary steerable chute located in the +Z bay, and a convention Ringsail parachute backup located in the +Y bay. Structurally, the forward bulkhead will be modified to accept the new parachutes, the added drogue chute mortar, the revised uprighting system bags, and the parachute thruster mechanism.

In order to accommodate the installation of four new retro-rocket structure support assemblies, located in the aft compartment area between #2 and #3, frames #10 and #11, frames #13 and #14, and frames #23 and #24, the inner crew compartment aft sidewall (Figures 13 and 14) will be modified as follows:

1) To permit installation of the retro-rocket support structures, the aft sidewall inner skin weld assembly will be modified by incorporating in pairs, eight machined fittings, in the areas of the frame locations identified above. This change will require a rework of two major weld jigs, as well as coordinating master tooling (master model and tool masters), to control location of the fittings.

2) The aft sidewall primary bond assembly will be modified to accept the eight new machine fittings in the inner skin assembly. This will necessitate the rework of one major bond jig.

SYSTEMS SUPPORT STRUCTURE

The parachute recovery system support structure, located in the command module forward equipment compartment will be modified for accommodation of the Parasail steerable parachute system. The drogue and main chute disconnect "flower-pot" assembly will be modified to accommodate the new parachute riser assembly configuration. The structural attach points and confluence point, as well as basic configuration, will be retained. Fabrication and assembly will not be affected. However, the major special tool to hold the assembly in proper relationship and drill all attach holes will require rework. The following changes are required:

1. Two motor actuated winch assemblies will be added to support the steerable parachute operations. These winches will be bolted to the side of the thruster assemblies. Apply and drill jigs will be necessary to properly locate these assemblies and to drill all attach holes.

2. The structural support for the parachute installation will be revised to accommodate the new parachute system. This change will not impact or increase basic tooling, fabrication, or assembly time.

3. Incorporating the new parachute system will require modification of the four thruster assemblies. Two thruster assemblies will be revised to accept the two new winch assemblies which will be mechanically attached to them.

4. Four parachute harness attach pyrotechnic disconnect assemblies will be added. This will result in a major structure revision to the thruster assemblies and an increase of fabrication and assembly time.

5. Attachment support is required for the added third drogue chute mortar. Fabrication and installation requirements of the drogue chute will increase. No additional basic tooling requirement is necessary.

6. The main display console support structure and navigation panel (Figure 20) will be modified to accept the CCTV tube and mirror located in the structure behind the navigation panel. The panel itself will be changed to include a hinged door, to be opened for TV viewing, and a control switch for changing the RCS control arm from the RCS control mode to the steerable parachute mode. This will result in a high degree of change to this assembly, requiring a major change to the main assembly jig, and a family of master tooling for control of interchangeable attach hole pattern between the structure assembly, TV tube and switch assembly. In addition, apply jigs will be necessary for locating and drilling parts and components.

The command module aft compartment area (Figure 16) will be extensively reworked to support installation of the retro-rocket motor assemblies, ground sensor subsystem and vision subsystem. The necessary changes are:

1. A revision of frames #2, #3, #10, #11, #13, #14, #23, and #24 will be required to provide for the installation of the landing rocket assemblies. Frames #2, #3, #13, #14, #19, and #20 will be revised

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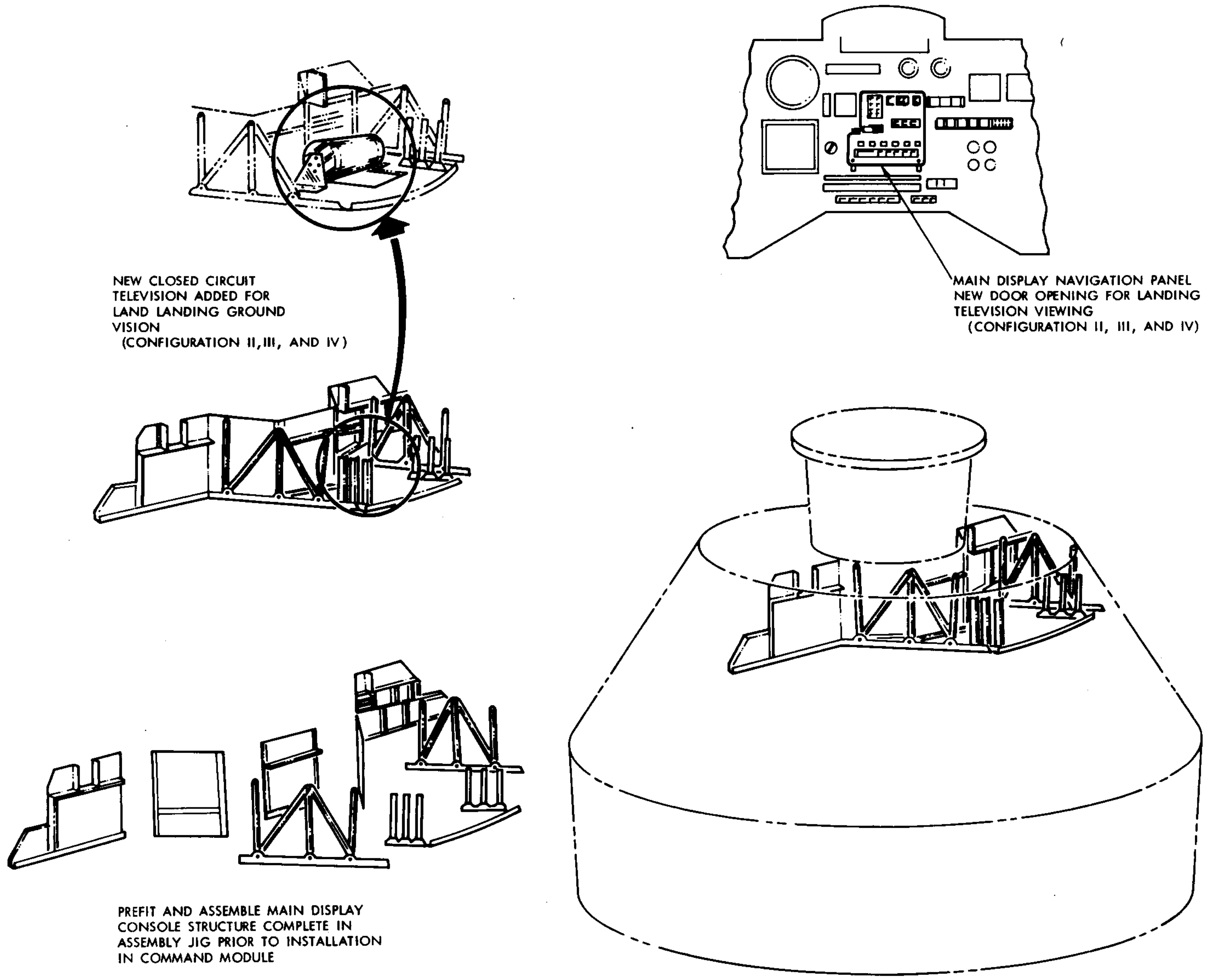

Figure 20. AES System Support Structure, Main Display Assembly

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to support relocation of a helium tank, uprighting system compressor, and potable water tank. These frames will also be modified to permit rerouting of the electrical wiring bundle. No major tooling change is required.

2. Four retro-rocket structure support assemblies will be required to allow installation of the retro-rocket motors. Three of the four assemblies will be of similar configuration. One will be fabricated to house the ground sensing radar and infrared altimeters, and the vision subsystem television camera. New assembly jigs will be required to assemble the four assemblies prior to installation on the inner crew compartment. A family of tooling masters will be needed to control interchangeable attach provisions between the purchased retro-rocket motors, radar and infrared altimeter, TV camera, and the structure support assembly.

3. Tool masters will be furnished to the equipment vendors by S&ID to ensure this control. Drill jigs will be necessary for drilling attach holes in the aft sidewall attach fittings. Fabrication, assembly, and installation operations will increase to fabricate and install this structure support.

HEAT SHIELD

The basic configuration of the heat shield will remain the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for access panel doors and exhaust openings being added to support the retro-rocket motor assembly installation.

Crew Compartment Heat Shield

The crew compartment heat shield aft section (Figure 17) will have a major revision to incorporate four new access panel doors, one each between frames #2 and #3, #10 and #11, #13 and #14, and #23 and #24, to provide accessibility to the retro-rocket assemblies. This will involve an extensive modification of the honeycomb panel assemblies in the area of the subject doors. The fabrication, assembly, and installation requirements will be increased for fabrication of four new doors. The basic tooling supporting this heat shield assembly will require extensive modification, as will all supporting master tooling (master model, tool master, etc.). This is a significant tooling change.

Aft Heat Shield

The aft heat shield (Figure 18) will be modified to incorporate four retro-rocket exhaust plugs. Three of these will be similar, and one will additionally accommodate the ground sensing radar and infrared altimeters and the television camera. The following changes to the aft heat shield are necessary:

1) The aft heat shield honeycomb panel assembly will be modified to include four cutouts to accept machined cup fittings. The areas of the cutouts will necessitate structural reinforcement to allow for attachment of the cup fittings and a thruster mechanism for ejecting an ablative plug. Assembly and installation operations will be increased to make the cutouts and install the fittings and thruster mechanism. A major assembly drill jig will be reworked to make the necessary cutouts and will be mastered by control tooling to assure proper location of the cutouts.

2) Four exhaust plug machined fittings will be fabricated to provide for operation of the retro-rocket motors. Three fittings will be similar and one will also provide for the ground sensing radar and infrared altimeters and the television camera. No major tooling changes are necessary.

3) An ablative plug will be added in the outer ablative installation in conjunction with the exhaust plug fitting. This change will be accomplished by a subcontractor.

4) Four thruster mechanisms will be installed on the aft heat shield to eject the ablative plugs. No basic tooling changes are required for installation of the assemblies.

INSTALLATION ANALYSIS

Configuration II will use a Parasail steerable parachute system, operated by two motorized winches. These winches are actuated by the existing RCS rotational hand controller. This will require new mock-up and wiring changes. The RCS panel and controller space will be used for switching from RCS mode to parachute winch operation. The four new configuration retro-rockets will be relocated in the aft heat shield. The positioning of the rockets will require relocation of the existing helium bottle, oxidizer tank, potable water tank, and the flotation system compressor. Relocation of the above existing components will necessitate mock-up and the fabrication of new tubing details.

The associated components of the retro-rocket installation include redundant altimeters, one radar and one infrared, logic network, sequencers, cabin viewing screen, and ignition squibs. All of these items will require electrical mock-up effort and the fabrication and installation of new wire harnesses.

The installation of the associated components will require additional shelving and bracketry for mounting.

MANUFACTURING SCHEDULE ANALYSIS

Schedule consideration for Configuration II considers the utilization of four new retro-rockets located in the command module aft equipment compartment; a ground sensing system consisting of radar and infrared altimeters;

and a vision subsystem utilizing closed circuit TV. A revision to the present Apollo earth recovery system is also required to incorporate a Parasail steerable parachute recovery system utilizing four point suspension. The Manufacturing functions effected are shown in Figure 21.

Schedule consideration will be required for the revision to the inner crew compartment aft sidewall to support the retro-rocket assemblies. The eight matching fittings required will necessitate review of procurement lead times to establish early procurement release. The command module inner structure forward equipment area will require modification to incorporate structural changes for the revised earth recovery system, but will have minimum schedule impact to the present AES Manufacturing Plan. The aft heat shield will be effected as a result of changes to the basic Aeronca heat shield panels required for weight reduction and also for incorporation of four retro-rocket exhaust openings.

The aft crew compartment heat shield will require schedule consideration for incorporation of four new access panel doors. This will result in major modification to basic assembly tooling as well as master tooling. Sufficient tool rework turn-around time will be necessary in order to affect the extensive modification without seriously impacting AES Manufacturing schedules. Mechanical systems, plumbing installation, electrical installation, and main display console installation will be affected by this configuration. The main display console will be extensively modified to support the requirement for TV receiver and support components. Changes to the main assembly jig and supporting detail tools will require schedule consideration for compatibility with presently planned Manufacturing requirements.

From a manufacturing and scheduling standpoint, Configuration II will result in an impact to presently proposed Manufacturing schedules, tooling, and equipment utilization. A significant increase in tooling rework and quantity of affected structural components in relation to the AES configuration baseline. However, no new long lead time procurement items are affected by this change, with the exception of Aeronca heat shield panel requirements previously discussed.

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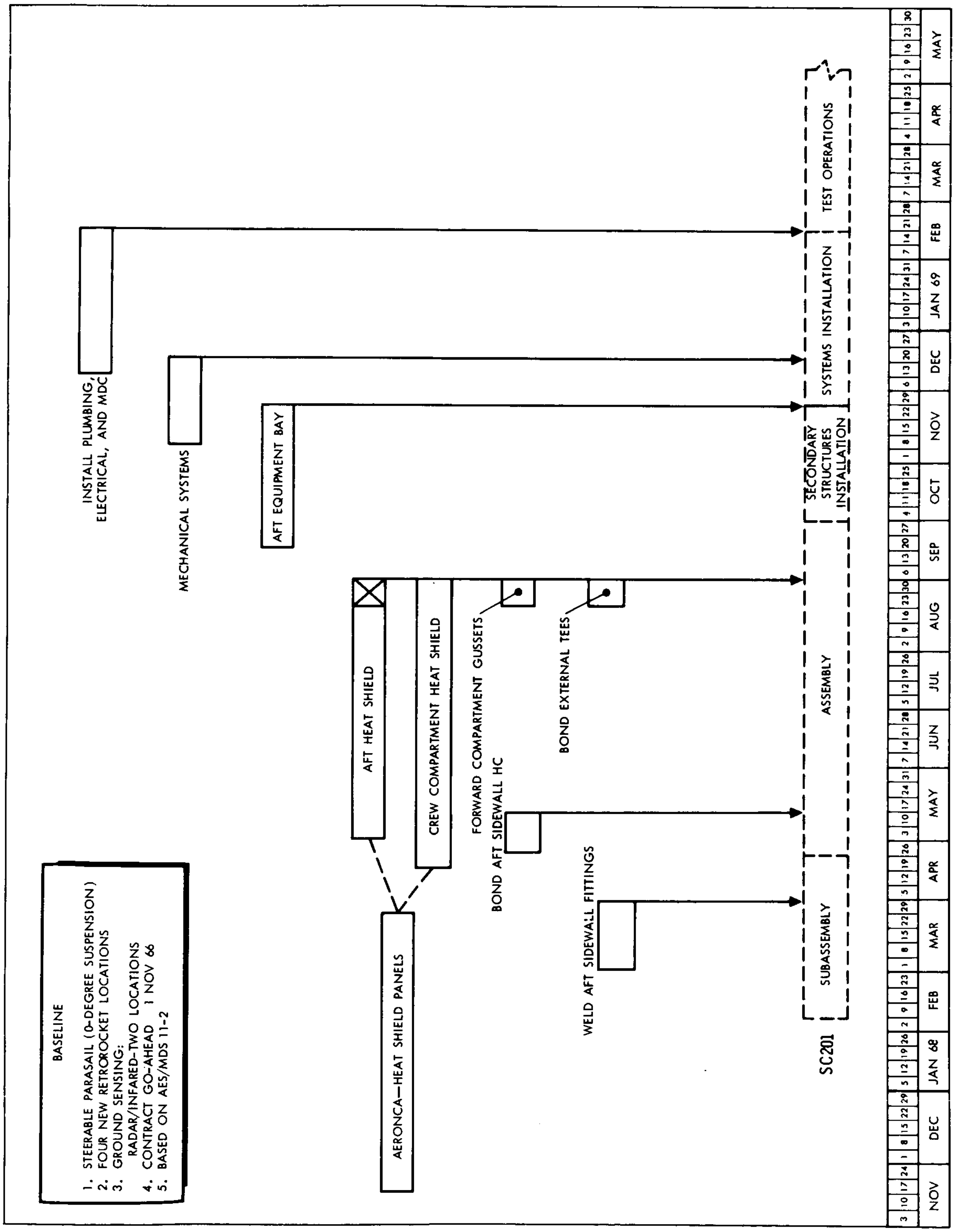

Figure 21. AES/LLS Configuration II Manufacturing Schedule

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CONFIGURATION III

Configuration III is identical to Configuration II with the exception of the steerable parachute. Configuration III uses a Cloverleaf parachute recovery system rather than a Parasail recovery system.

COMMAND MODULE INNER STRUCTURE

The basic configuration of the command module inner structure will remain essentially the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for certain structural revisions to provide for installation of Land Landing Subsystem, Configuration III.

INNER CREW COMPARTMENT

The inner crew compartment forward equipment area (Figure 12) will be revised to accept a Cloverleaf steerable parachute recovery system with a primary steerable chute located in the +Z bay, and a convention Ringsail parachute backup located in the +Y bay. Modifications are:

1. The forward bulkhead structure will be modified to accept the new parachutes, the added drogue chute mortar, the revised uprighting system bags, and the parachute thruster mechanism.

2. The inner crew compartment aft sidewall (Figures 13 and 14) will be modified to accommodate the installation of four new retro-rocket structure support assemblies, located in the aft compartment area between #2 and #3, frames #10 and #11, frames #13 and #14, and frames #23 and #24.

3. To permit installation of the retro-rocket support structures, the aft sidewall inner skin weld assembly will be modified by incorporating in pairs, eight machines fittings, in the areas of the frame locations identified above. This change will require a rework of two major weld jigs, as well as coordinating master tooling (master model and tool masters), to control location of the fittings.

4. The aft sidewall primary bond assembly will be modified to accept the eight new machine fittings in the inner skin assembly. This will necessitate the rework of one major bond jig.

SYSTEMS SUPPORT STRUCTURE

The parachute recovery system support structure, located in the command module forward equipment compartment will be modified for accommodation of the Cloverleaf steerable parachute system. The drogue and main chute disconnect "flower-pot" assembly will be modified to accommodate the new parachute riser assembly configuration. The structural attach points and confluence point, as well as basic configuration, will be retained. Fabrication and assembly will not be affected. However, the major special tool to hold the assembly in proper relationship and drill all attach holes will require rework. Specific changes will be:

1. Two motor actuated winch assemblies will be added to support the steerable parachute operations. These winches will be bolted to the side of the thruster assemblies. Apply and drill jigs will be necessary to properly locate these assemblies and to drill all attach holes.

2. The structural support for the parachute installation will be revised to accommodate the new parachute system. This change will not impact or increase basic tooling, fabrication, or assembly time.

3. Incorporating the new parachute system will require modification of the four thruster assemblies. Two thruster assemblies will be revised to accept the two new winch assemblies which will be mechanically attached to them.

4. Four parachute harness attach pyrotechnic disconnect assemblies will be added. This will result in a major structure revision to the thruster assemblies and an increase of fabrication and assembly time.

5. Attachment support is required for the added third drogue chute mortar. Fabrication and installation requirements of the drogue chute will increase. No additional basic tooling requirement is necessary.

6. The main display console support structure and navigation panel (Figure 20) will be modified to accept the closed circuit TV tube and mirror, located in the structure behind the navigation panel. The panel itself will be changed to include a hinged door, to be opened for TV viewing, and a control switch for changing the RCS control arm from the RCS control mode to the steerable parachute mode. This will result in a high degree of change to this assembly, requiring a major change to the main assembly jig, and a family of master tooling for control of interchangeable attach hole pattern between the structure assembly, TV tube and switch assembly. In addition, apply jigs will be necessary for locating and drilling parts and components.

The command module aft compartment area (Figure 16) will be extensively reworked to support installation of the retro-rocket motor assemblies, ground sensor subsystem and vision subsystem. The necessary changes are:

1. A revision of frames #2, #3, #10, #11, #13, #14, #23, and #24 will be required to provide for the installation of the landing rocket assemblies. Frames #2, #3, #13, #14, #19, and #20 will be revised

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to support relocation of a helium tank, uprighting system compressor, and potable water tank. These frames will also be modified to permit rerouting of the electrical wiring bundle. No major tooling change is required.

2. Four retro-rocket structure support assemblies will be required to allow installation of the retro-rocket motors. Three of the four assemblies will be of similar configuration. One will be fabricated to house the ground sensing radar and infrared altimeters, and the vision subsystem television camera. New assembly jigs will be required to assemble the four assemblies prior to installation on the inner crew compartment. A family of tooling masters will be needed to control interchangeable attach provisions between the purchased retro-rocket motors, radar and infrared altimeter, TV camera, and the structure support assembly.

3. Tool masters will be furnished to the equipment vendors by S&ID to ensure this control. Drill jigs will be necessary for drilling attach holes in the aft sidewall attach fittings. Fabrication, assembly, and installation operations will increase to fabricate and install this structure support.

HEAT SHIELD

The basic configuration of the heat shield will remain the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for access panel doors and exhaust openings being added to support the retro-rocket motor assembly installation.

Crew Compartment Heat Shield

The crew compartment heat shield, aft section (Figure 17), will have a major revision to incorporate four new access panel doors, one each between frames #2 and #3, #10 and #11, #13 and #14, and #23 and #24, to provide accessibility to the retro-rocket assemblies. This will involve an extensive modification of the honeycomb panel assemblies in the area of the subject doors. The fabrication, assembly and installation requirements will be increased for fabrication of four new doors. The basic tooling supporting this heat shield assembly will require extensive modification, as will all supporting master tooling (master model, tool master, etc.). This is a significant tooling change.

Aft Heat Shield

The aft heat shield (Figure 18) will be modified to incorporate four retro-rocket exhaust plugs. Three of these will be similar, and one will additionally accommodate the ground sensing radar and infrared altimeters and the television camera. The following changes to the aft heat shield are necessary:

1. The aft heat shield honeycomb panel assembly will be modified to include four cutouts to accept machined cup fittings. The areas of the cutouts will necessitate structural reinforcement to allow for attachment of the cup fittings and a thruster mechanism for ejecting an ablative plug. Assembly and installation operations will be increased to make the cutouts and install the fittings and thruster mechanism. A major assembly drill jig will be reworked to make the necessary cutouts and will be mastered by control tooling to assure proper location of the cutouts.

2. Four exhaust plug machined fittings will be fabricated to provide for operation of the retro-rocket motors. Three fittings will be similar and one will also provide for the ground sensing radar and infra-red altimeters and the television camera. No major tooling changes are necessary.

3. An ablative plug will be added in the outer ablative installation in conjunction with the exhaust plug fitting. This change will be accomplished by a subcontractor.

4. Four thruster mechanisms will be installed on the aft heat shield to eject the ablative plugs. No basic tooling changes are required for installation of the assemblies.

INSTALLATION ANALYSIS

Configuration III will use a Cloverleaf steerable parachute system, operated by two motorized winches. These winches are actuated by the existing RCS rotational hand controller. This will require new mock-up and wiring changes. The RCS panel and controller space will be used for switching from RCS mode to parachute winch operation. The four new configuration retro-rockets will be relocated in the aft heat shield. The positioning of the rockets will require relocation of the existing helium bottle, oxidizer tank, potable water tank, and the flotation system compressor. Relocation of the above existing components will necessitate mock-up and the fabrication of new tubing details.

The associated components of the retro-rockets installation include redundant altimeters - one radar and one infra-red, logic network, sequencers, cabin viewing screen and ignition squibs. All of these items will require electrical mock-up effort and the fabrication and installation of new wire harnesses.

The installation of the associated components will require additional shelving and bracketry for mounting.

MANUFACTURING SCHEDULE ANALYSIS

Schedule considerations for Configuration III considers the utilization

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of four new retro-rockets located in the command module aft equipment compartment; a ground sensing system consisting of radar and infra-red altimeters; and a vision subsystem utilizing closed circuit TV. A revision to the present Apollo earth recovery system is also required to incorporate a Cloverleaf steerable parachute recovery system utilizing four point suspension. The Manufacturing areas affected are shown in Figure 22.

Schedule consideration will be required for the revision to the inner crew compartment aft sidewall to support the retro-rocket assemblies. The eight machine fittings required will necessitate review of procurement lead times to establish early procurement release. The command module inner structure forward equipment area will require modification to incorporate structural changes required for the revised earth recovery system, but will have minimum schedule impact to the present AES Manufacturing plan. The aft heat shield will be affected as a result of changes to the basic Aeronca heat shield panels required for weight reduction and also for incorporation of four retro-rocket exhaust openings.

The aft crew compartment heat shield will require schedule consideration for incorporation of four new access panel doors. This will result in major modification to basic assembly tooling as well as master tooling. Sufficient tool rework turn-around time will be necessary in order to affect the extensive modification without seriously impacting AES Manufacturing schedules. Mechanical systems, plumbing installation, electrical installation, and main display console installation will be affected by this configuration. The main display console will be extensively modified to support the requirement for TV receiver and support components. Changes to the main assembly jig and assigned detail tools will require schedule compatibility with presently planned Manufacturing requirements.

From a manufacturing and scheduling standpoint Configuration III will result in an impact to presently proposed Manufacturing schedules, tooling and equipment utilization.

Configuration III reflects a significant increase in tooling rework and quantity of affected structural components in relation to the AES baseline. However, no new long lead time procurement items are affected by this change, with the exception of Aeronca heat shield panel requirements previously discussed.

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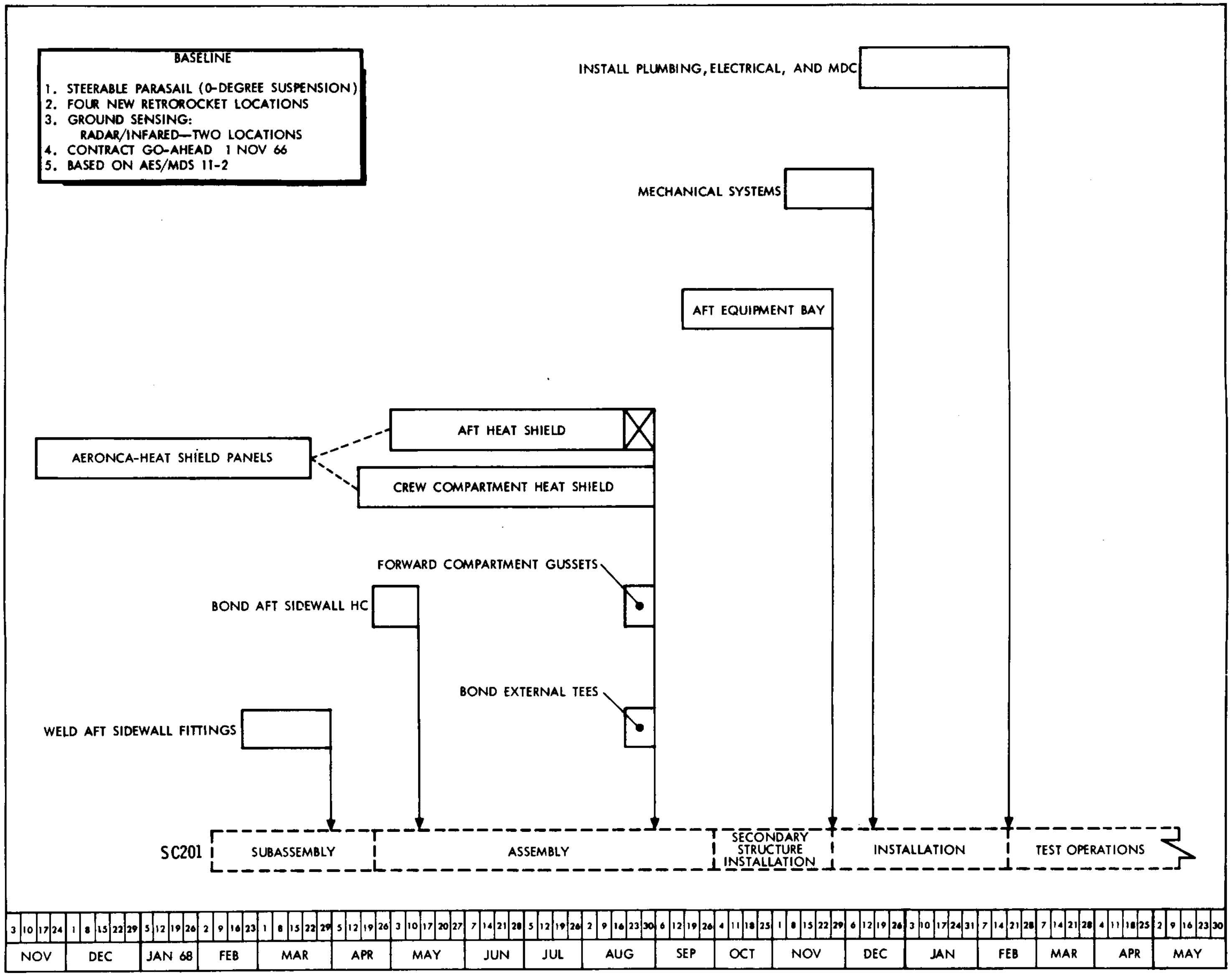

Figure 22. AES/LLS Configuration III Manufacturing Schedule

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CONFIGURATION IV

The necessary structural fabrication and assembly changes, and tooling modifications, required to incorporate Configuration IV into the spacecraft are as follows:

COMMAND MODULE INNER STRUCTURE

The basic configuration of the command module inner structure will remain essentially the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for certain structural revisions to provide for installation of the land landing subsystem.

INNER CREW COMPARTMENT

The inner crew compartment forward equipment area (Figure 12) will be revised to accept a Parasail or Cloverleaf steerable parachute recovery system, and a retro-rocket motor installed in the parachute riser assembly. The three Block II Ringsail parachutes will be removed and replaced with either a Parasail or Cloverleaf single steerable parachute system utilizing a conventional Ringsail backup chute. This will require a revision of the parachute attach bracketry.

SYSTEMS SUPPORT STRUCTURE

The parachute recovery system support structure, located in the command module forward equipment compartment will be extensively modified to provide for incorporation of the proposed steerable parachute system (Figure 15). The drogue and main chute disconnect "flower-pot" assembly will be modified to accommodate the new parachute riser assembly configuration. The structural attach points, confluence point, and the basic configuration will be retained. Fabrication and assembly effort will remain the same. A major special tool to hold the assembly in proper relationship while drilling attach holes will require rework. The "flower-pot" assembly will require modification.

Two motor actuated winch assemblies will be added to support steerable parachute operation. These winches will be located on the side of the thruster assemblies by bolt attachment. Apply and drill jigs will be necessary to properly locate these assemblies and drill attach holes.

The structure support for the parachute installation will be modified to accommodate the new parachute system. This modification will not require a basic tooling change nor increase fabrication or assembly time.

The four thruster assemblies will require modification for incorporating the new parachute system. These structure assemblies will be revised to accept the two new winch assemblies mechanically attached to them.

Four parachute harness attach pyrotechnic disconnect assemblies will be added. This will result in a major structure revision to the thruster assemblies and an increase in fabrication and assembly time.

The addition of a third drogue chute mortar will require attachments. No basic tooling change requirement is necessary.

The retro-rocket motor located in the forward equipment compartment will require a structure support assembly (Figure 23). This assembly will be attached to the forward bulkhead and access cylinder. An assembly jig will be required to assemble the structure assembly prior to installation in the command module primary structure. Master tools will be necessary to control attach points.

The main display console structure and navigation panel (Figure 20) will be modified to accept a TV screen located in the structure behind the navigation panel. The panel itself will be changed to include a hinged door to be opened for TV viewing and a control switch for changing the RCS control arm from the RCS mode to a steerable parachute mode. This will result in a high degree of change to this assembly requiring a major change to the main display assembly jig, and a family of master tooling for control of interchangeable attach hole pattern between the structure assembly and the TV receiver and switch assembly. Additional apply jigs will be necessary for locating components and drilling attach holes.

The command module aft compartment area (Figure 6) will be revised by adding a deployable shelf assembly which will house the ground sensing radar and infra-red altimeters, and the television camera. This assembly will consist of a shelf mounted on a rail track and operated by a thruster mechanism. A new jig will be required to assemble the shelf prior to installation on the command module aft sidewall. Master tooling will be required to control attach hole patterns between the shelf assembly and the radar and infra-red altimeters, television camera, and aft sidewall. Tool masters will be supplied by S&ID to the equipment vendors to ensure this control. Drill jigs will be necessary for drilling all attach holes. Fabrication, assembly, and installation will be increased to fabricate and install this structure support assembly.

HEAT SHIELD

The basic configuration of the heat shield will remain the same as shown in the AES Preliminary Manufacturing Plan, SID 65-1146, except for an ejection panel door located in the crew compartment heat shield-aft section (Figure 7) to provide for the deployment of a shelf which houses the ground sensing radar and infra-red altimeters and a television camera for the vision subsystem. The fabrication and installation hours will be minimal to fabricate and install the new panel door and thruster mechanisms. One major assembly tool, which trims, decores, and welds the extruded edge members to the honeycomb panel assemblies, will be modified to accommodate the new door configuration.

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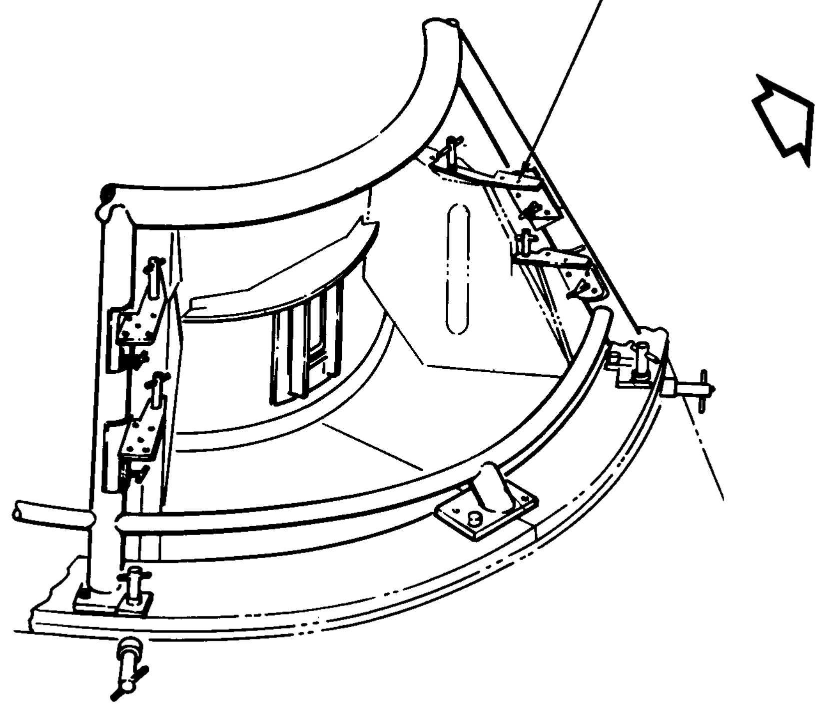

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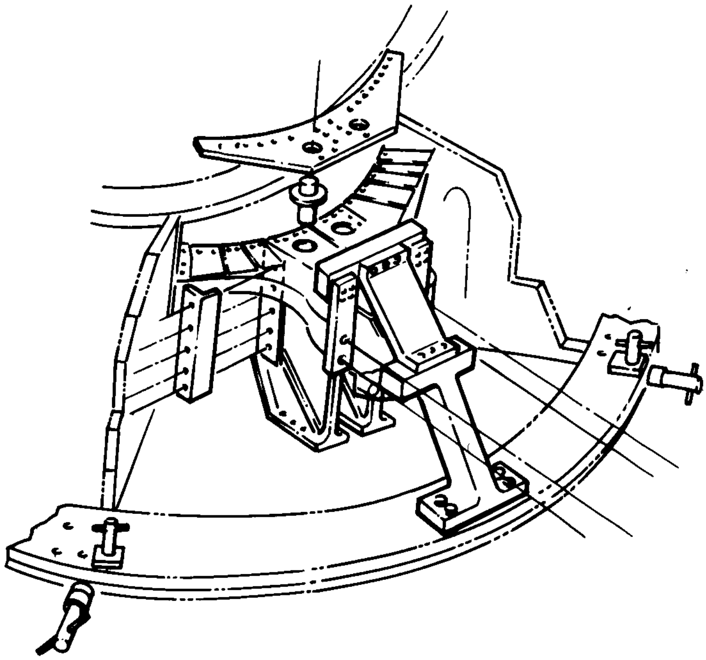
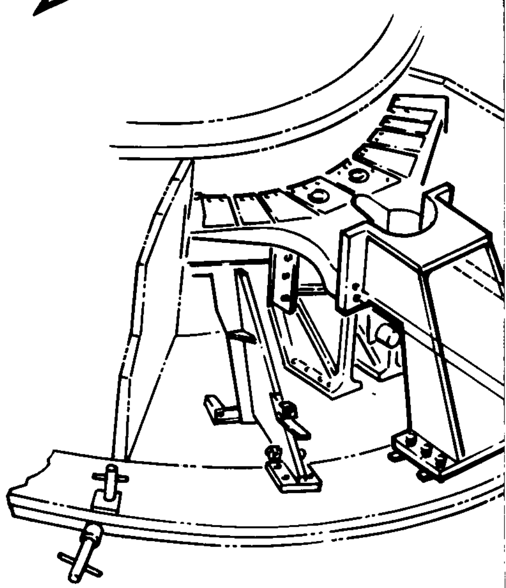


LOCATE TWO VERTICAL MACHINED FRAMES,
BEAM, AND TEES, AND DRILL ALL
ATTACH HOLES AND INSTALL IN PLACE

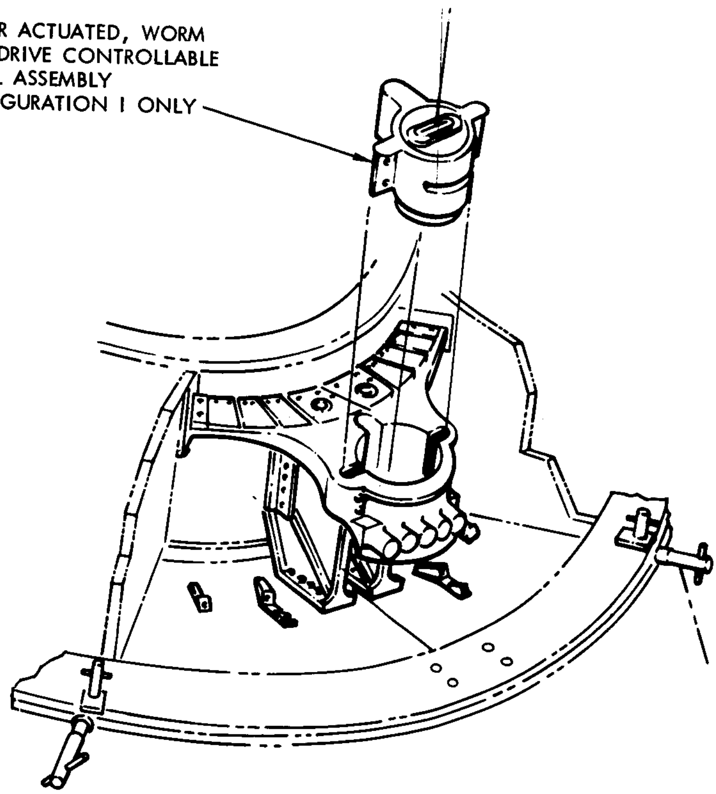


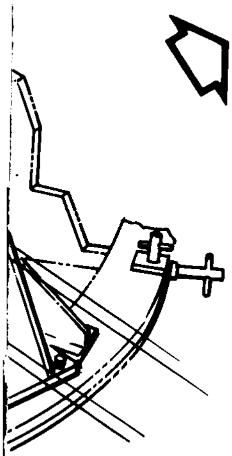
DRILL AND REAM IN-LINE HOLE
INSTALLATION OF DROGUE AN
CHUTE DISCONNECT ASSEMBLY

DRILL AND INSTALL FITTINGS O
FORWARD BULKHEAD

Figu

FOLD-OUT
#2





re 23. AES Command Module Forward Equipment Compartment
Parachute Structure Arrangement

FOLD-OUT #3

[redacted]

INSTALLATION ANALYSIS

Configuration IV has a single multi-nozzle retro-rocket suspended in the parachute risers instead of the four aft heat shield mounted units used in the other configurations. All basic installation operations remain the same as those of Configuration III. The location of the two altimeter antennas and TV camera is changed to an existing lower equipment bay panel which is hinged to rotate out of the side of the command module. This relocation would not change the installation sequence or timing.

To accommodate the actuation of the riser mounted retro-rocket, new wire harnesses, as well as a new forward deck umbilical, will be required. The fabrication and installation effort and scheduling of these harnesses is similar to the harnesses required for either of the previous two configurations.

MANUFACTURING SCHEDULE ANALYSIS

Fabrication scheduling requirements for this configuration consider the utilization of a single retro-rocket motor, deployed in the parachute recovery system, riser assembly; a steerable Cloverleaf parachute recovery system; and a ground sensing system, consisting of radar and infra-red altimeters located in the aft equipment compartment.

The Manufacturing functions effected are shown in Figure 24. As identified, the inner crew compartment aft sidewall will be revised to incorporate provisions for a deployable shelf structure, to house the ground sensing system. This change represents minimum impact to presently programmed Manufacturing schedules.

To support the single retro-rocket motor in the parachute riser assembly, some modification to the forward equipment area will be required to support changes to hardware installation. Assembly sequence adjustments will be necessary to accommodate this change.

The crew compartment aft heat shield will require schedule consideration for incorporation of an ejectable door panel to provide for deployment of the ground sensing system. This change will have minimum impact on Manufacturing schedules. The aft heat shield will be effected as a result of the necessity for weight reduction in the Aeronca heat shield panels. Schedule consideration will be necessary to effect timely material release in support of procurement lead times. Since this configuration requires no penetrations in the aft heat sheild, no structural assembly changes are required.

This configuration results in the least schedule impact to Manufacturing of the four configurations studied. The quantity of components effected and the number of tools requiring rework can be incorporated with minimum disruption of the present command module structural and system requirements.

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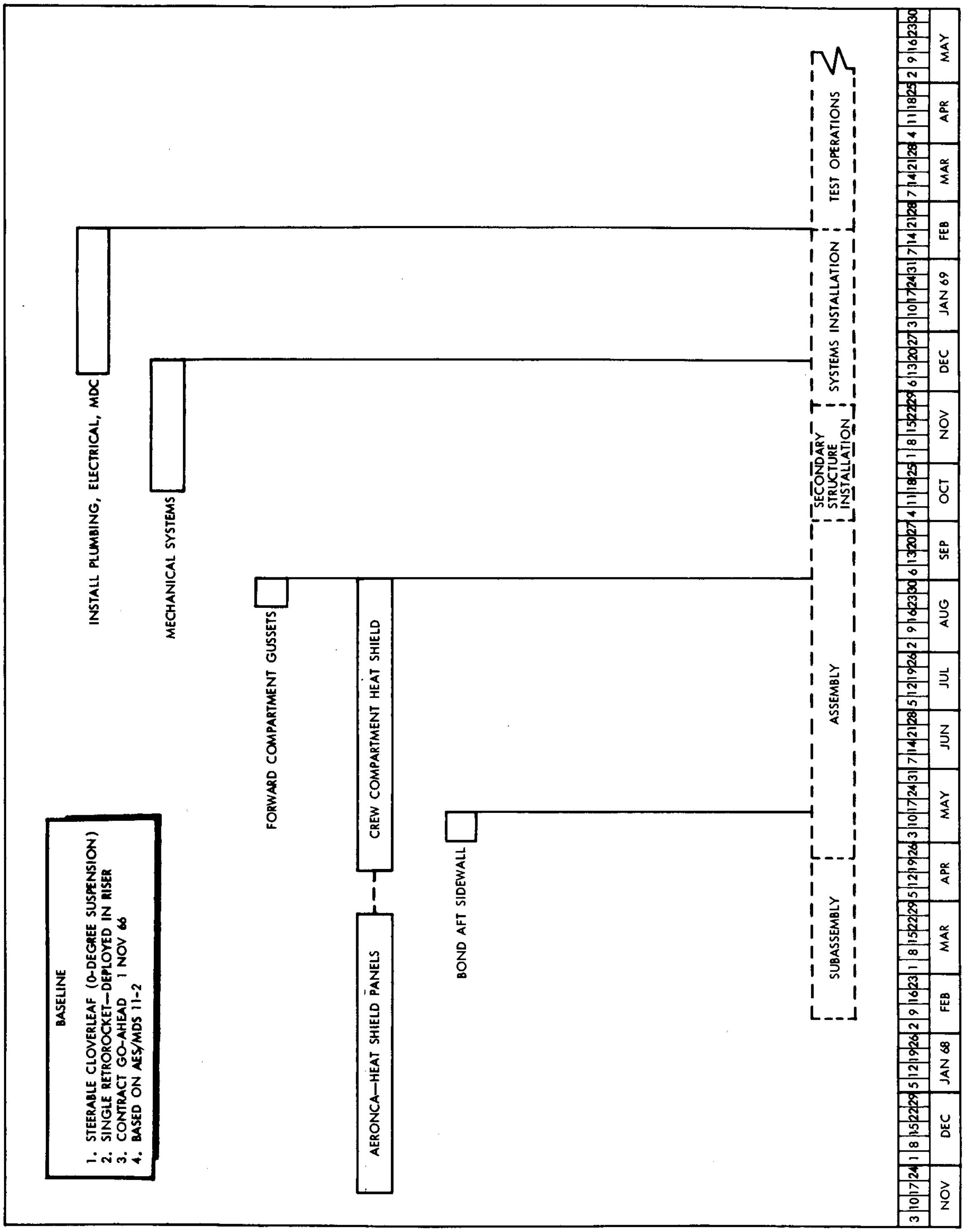


Figure 24. AES/LLS Configuration IV Manufacturing Schedule

[redacted]

[redacted]

MANUFACTURING CHECKOUT ANALYSIS

CONFIGURATION I

The additional testing to be performed by Manufacturing for Configuration I would be limited to electrical harness continuity and insulation resistance testing. To perform an in-house test on the new sequencer, the existing bench maintenance GSE model C14-126 would require minor modification. If new component connectors are utilized, mating connector adapters will be required as additional factory test equipment.

CONFIGURATION II

The addition of two altimeters in place of the visual system and sensor probes for Configuration II has increased the test requirements. Besides the normal continuity and insulation resistance test performed on all NAA fabricated cables and harnesses, the manufacturing bench maintenance capabilities must be expanded to encompass radar, infra-red and CCTV bench check capability. The addition of this capability will require six new bays of electrical/electronic consoles and the modification of the existing bench maintenance equipment landing system sequencer and baroswitch test unit. An estimated 20 percent modification of BME models C14-126 and C14-002 would be required. A unit of factory test equipment is required to supply stimuli and receive readout of control reel rates and travel for the two motorized winches on the forward deck. A bench maintenance single bay console is required to provide a bench check of systems components. All other test requirements of Configuration I would all be required for Configuration II.

CONFIGURATION III

The change of the parachute from Parasail (Configuration II) to Cloverleaf (Configuration IV) will not effect the manufacturing test and checkout sequence, timing, or equipment from that projected for Configuration II.

CONFIGURATION IV

Checkout and test requirements for Configuration IV require equipment similar to that projected for Configuration III. The location of the single multi-nozzle retro-rocket on the parachute deck would require an electrical harness check similar to those applied to the other configurations. Installation of the live rockets is not performed at Downey, therefore, only a physical configuration fit check of the retro-rocket attachments will be performed by manufacturing. All electrical harnesses will be checked for continuity and insulation resistance.

[redacted]

Factory test equipment required to support all concepts of the Land Landing systems installation and checkout cycle is tabulated in Table 2. In addition to the Factory Test Equipment listed, Manufacturing will utilize existing supply contract Standard Test Equipment, such as the following:

1. Automatic Electrical Circuitry Continuity Analyzer (DITMCO), Figure 25.
2. Gage and Meter Calibration Equipment.
3. General Purpose Gages and Meters.

Table 2. Factory Test Equipment

Equipment Description or Title	Physical Configuration	Requirement			
		Configuration			
		I	II	III	IV
Electro-Mechanical Sensor	Equivalent of a 2 Bay Console	X			
Retro-Rocket Fit-Check Unit	Inert Retro-Rocket	X	X	X	X
Parachute Mechanical Assembly and Control Test Unit	Equivalent of a 2 Bay Unit with Auxiliaries		X	X	X
Radar, Infra-Red and TV Bench Maintenance Equipment	Equivalent of a 6 Bay Console		X	X	X
Continuity Analyzer Test Cables and Programming	Cable Set and Test Tape	X	X	X	X

CO[redacted]

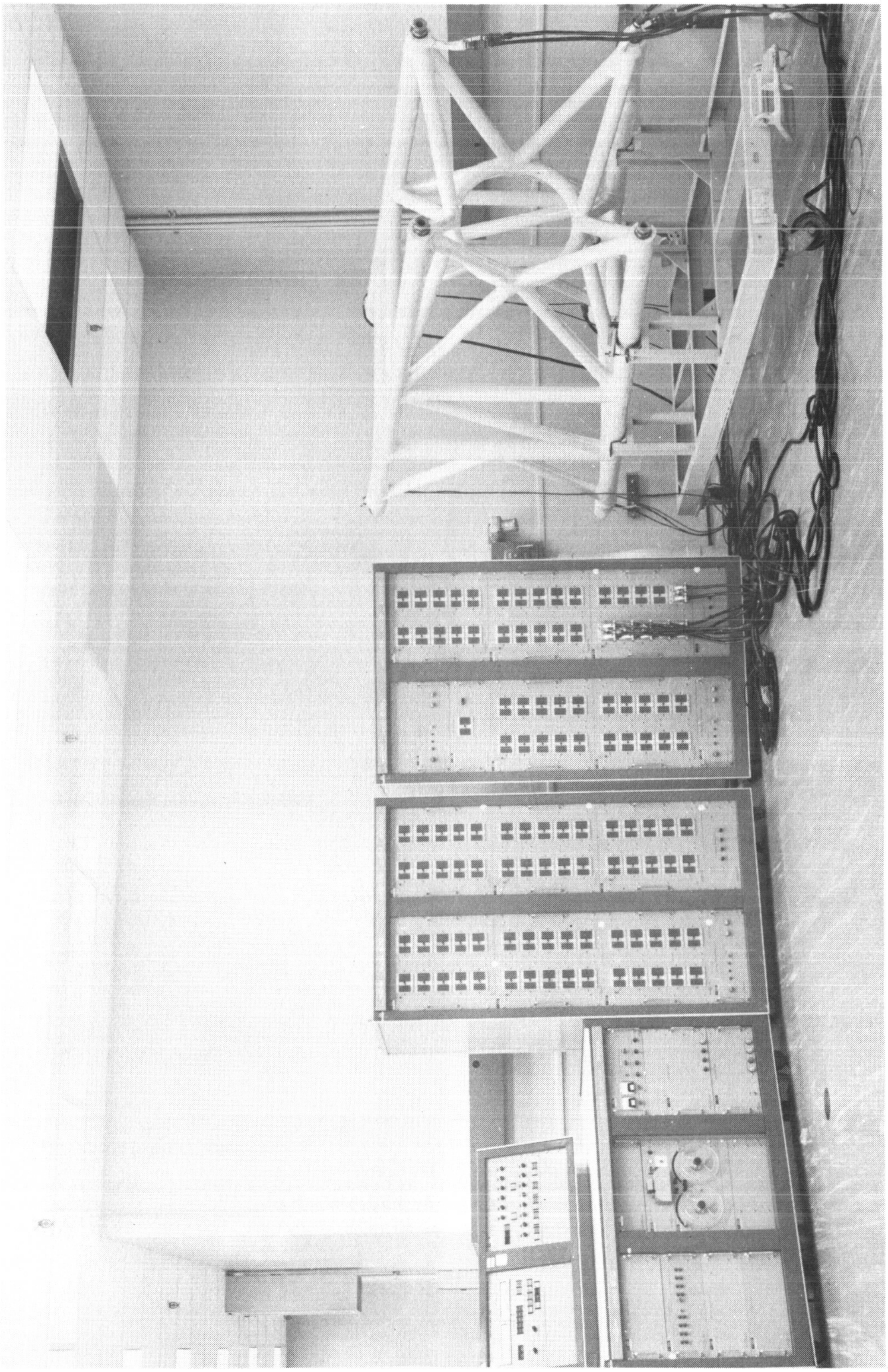


Figure 25. Tape-Operated Automatic Continuity Analyzer

CONFIDENTIAL

TEST OPERATIONS

Test operations planning analyses were conducted to determine program implementation requirements for the various AES Land Landing System concepts. Program planning factors examined related to House spacecraft and thermal-vacuum spacecraft testing, an aerial drop test program, the heat shield qualification re-entry test, and flight vehicle checkout operations. This development test program supplements the requirements contained in Report SID 65-1544-1. Test requirements of the land landing system were compared with those of the basic Apollo Block II Earth Landing System in the AES spacecraft. Analyses have not revealed any major impact of the LLS on either Downey or field operations. GSE requirements slightly increase proportional to the selected system complexity. However, the major impact of LLS is due to the required development and qualification test programs.

AERIAL DROP TEST PROGRAM

The aerial drop test program will be conducted at the El Centro site utilizing boilerplate and flight structure CM test vehicles and a C 133 aircraft. The program is designed to qualify the LLS through high altitude drop tests terminating with functional demonstration of the integrated LLS.

The program will be conducted by NAA with rigging support by the parachute supplier and subcontract support of the carrier aircraft. A field test team will be located at El Centro for operation of the test vehicles, including on-site refurbishment between drops, and operation of the Mobile Ground Station. Test planning, engineering and test data processing support will be provided at S&ID Downey.

A boilerplate CM will be used in final qualification of the parachute subsystem. It will contain, in addition to the parachute and sequencer system, an instrumentation system consisting of sensors, signal conditioners, on board recording system and telemeter. A radio command receiving system will be used for ground back up to the sequencing system. The extent of steering tests to be performed with the boilerplate is yet to be defined. It is anticipated that at least the capability of remote control will be demonstrated in support of subsequent integrated systems tests in a CM Integrated LLS test vehicle of actual flight structure.

The integrated aerial drop test vehicle will contain the complete LLS and sequencer system. Drops will include steering, slewing remote ground control, and retro-rocket system firings. Remote steering will require RF transmission of the on-board TV signal. The ground controller will essentially operate the steering as though they were in the CM viewing the LLS controls and displays and TV landing area picture.

Implementation of these programs requires the drop test vehicle, supporting GSE, carrier aircraft, field crew, spares and materials, on-site support services, and normal elements of field support from the home plant. The schedule for these tests is shown in Figure 37 LLS Master Schedule.

CONFIGURATION I

Configuration I requires only the integrated system aerial drop tests, as the parachutes are already qualified by Apollo use. A flight structure CM will be equipped with the parachute swivel system including control, landing retro-rocket system, probe for sensing altitude and initiating retro-ignition, heat shield plug thruster system, test heat shield and instrumentation system. While Configuration I does not employ a closed loop TV system, one will be used for remote control purposes. The mobile ground station will be as described in the Development Engineering section of this report.

The test vehicle will be completely assembled, including instrumentation prior to delivery to the test site. The baseline plan does not include Downey checkout.

Following checkout in the field, six drops will be made from a C-133 aircraft.

CONFIGURATION II

The aerial drop test program for Configuration II will use both the boilerplate and flight structure test CM's.

Qualification Tests

Nine drops are programmed for the final qualification of the parachute system utilizing the boilerplate vehicle.

This will include initial test of the parachute steering. Further detail analysis is required to resolve whether an on-board programmer or remote control will be used for steering test purposes. The latter would require inclusion of a TV system and a more sophisticated radio command system than for sequencer back-up. Use of remote steering would, however, provide improved development phasing in preparation for integrated system tests. Potentially, initial flights would be for parachute performance test only with each flight becoming more sophisticated.

Integrated Drop Tests

Six drops are programmed for the flight structure test CM's.

The complete LLS system and sequencer would be installed in this Integrated Aerial Drop test vehicle. The configuration at delivery would include the instrumentation system, radio command system, and TV transmitting system required for test. Downey checkout is not programmed in the baseline plan. The vehicle would be delivered to the field site following manufacturing systems installation. Field checkout and flight operations are programmed over an eleven month period.

CONFIGURATION III

Test operations for Configuration III will be the same as Configuration II.

CONFIGURATION IV

Test operations for Configuration IV will be the same as Configuration II except this configuration requires no heat shield plug thruster tests, but requirements are added for verifying operation of the foldout door which supports the altitude sensors elements and TV viewer.

HOUSE SPACECRAFT PROGRAM

The Block II House Test Model, 2H-1 will be used for appropriate initial testing. While the CSM systems are not the same as for the AES Phase II spacecraft certain LLS objectives can be achieved.

1. This configuration supports those systems which will be used for unmanned re-entry demonstration of the heat shield.

2. Test on 2H-1 can provide an early engineering development support evaluation (seven months before the AES House Test Model is available) of interaction with other CM operations.

The Block II House Test Model cannot provide form and fit compatibility verification. Mockups prepared during FDP will be used to satisfy related test requirements.

No additional facilities are required to support test on 2H-1. Additional resources requirements are related to GSE changes and new GSE required to support the LLS. Testing on 2H-1 would be conducted on a basis of non interference with the lunar landing program. 2H-1 is already programmed at a practical level of effort. In order to encompass the type of testing required of the LLS without a manpower increase, tests must be scheduled on a priority basis to remain within the capability of the established 2H-1 programs.

The AES House Test Model program is planned for integrated systems testing of the complete AES CSM. The LLS requirements would automatically be included. Again, testing must be scheduled on priority basis to remain within the program level of effort capability. House spacecraft testing will be further defined in sufficient detail during FDP to clearly identify schedule factors and firmly establish a program implementation plan.

CONFIGURATION I

Testing will be performed on 2H-1 in support of the re-entry test spacecraft. New GSE will be required to support the LLS and minor modifications will be required to the ACE-SC signal conditioning equipment.

The AES House Test Model will be phased in when it becomes available. The amount of testing directly attributable to Configuration I will be minimal by comparison to the overall AES house spacecraft test requirements. The applicable GSE used with 2H-1 will be used with minor changes related to interfaces between CSM systems.

CONFIGURATION II

Testing will utilize 2H-1 for early engineering support and test evaluation of the re-entry test vehicle configuration. GSE requirements will be

[redacted]

commensurate with the configuration.

The AES House Test Model will be phased in when it becomes available. The applicable GSE used with 2H-1 will be supplemented as necessary. Because of increased systems complexity, Configuration II requires a greater increase of GSE (over the Block II system baseline) than does Configuration I.

CONFIGURATION III

Test operations for Configuration III will be the same as Configuration II.

CONFIGURATION IV

Test operations for Configuration IV will be the same as Configuration II, except 2H-1 is not used in this concept because there is no requirement for tests related to a heat shield re-entry test vehicle.

THERMAL VACUUM SPACECRAFT TEST PROGRAM

The LLS will be incorporated in the Thermal Vacuum Test spacecraft during the CM modification period established by MDS 11-2 (Figure 36). Since the baseline AES plan assumes the NAA test force will be retained at the Clear Lake Facility between 2TV-1 and 3TV-1 test periods, there should be adequate manpower available. The LLS mod effort will, however, require materials and equipment support. The programmed AES Thermal Vacuum Spacecraft level of effort assumes operating at maximum capability of the one test vehicle during the time period pertinent to this discussion. Therefore, the LLS requirement merely identifies use of a programmed capability. The additional systems maintenance and operating task is an insignificant amount of the total spacecraft operations.

There are no test operations variations for the Thermal Vacuum Spacecraft between the four concepts. The only variations are GSE requirements.

[redacted]

HEAT SHIELD UNMANNED RE-ENTRY TEST

The objectives and requirements for this flight were discussed previously in the Development Test Section. The requirements for re-entry testing are identical for Configurations I, II or III; Configuration IV does not require this type of test, since the heat shield does not need to be modified. Program implementation planning of these requirements are briefly described here.

The re-entry test spacecraft will require a basic Block II CSM modified for this test by the addition of an AES LIS and an automatic system for operating control.

Downey and field test operations will be basically the same as for a Block II spacecraft. The configuration changes will add slightly to the operations times shown in Figures 26 and 27, which reflect typical operations schedules for Apollo Block II vehicles.

No analysis was made to determine the affect on flow of the Block II vehicles. This will depend on whether an existing Block II was refurbished as opposed to processing an additional spacecraft. In the latter case, rescheduling of other Block II vehicles will be required to avoid manpower and resources utilization transients.

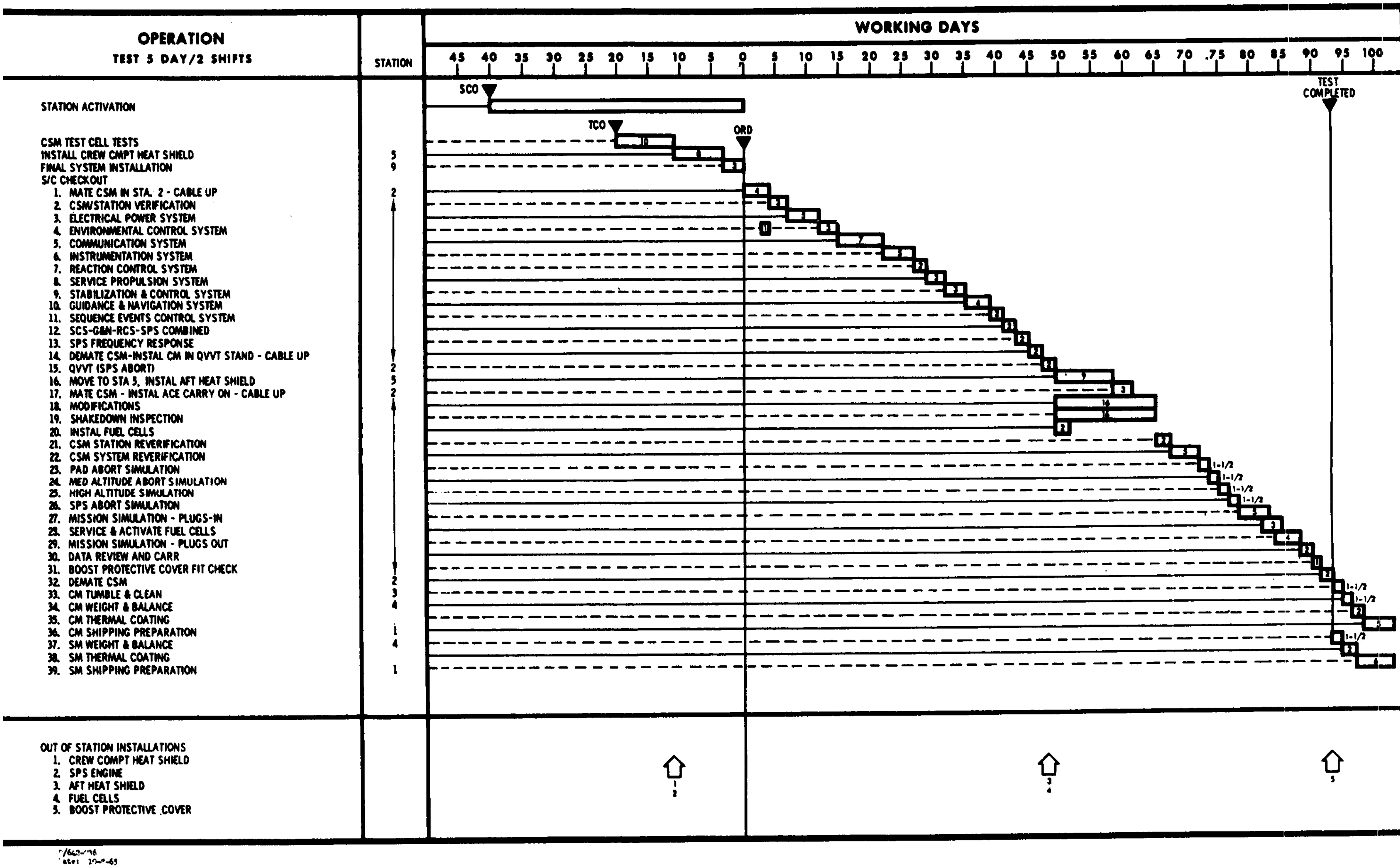


Figure 26. Typical Block II Spacecraft - Downey Checkout Schedule

[redacted]

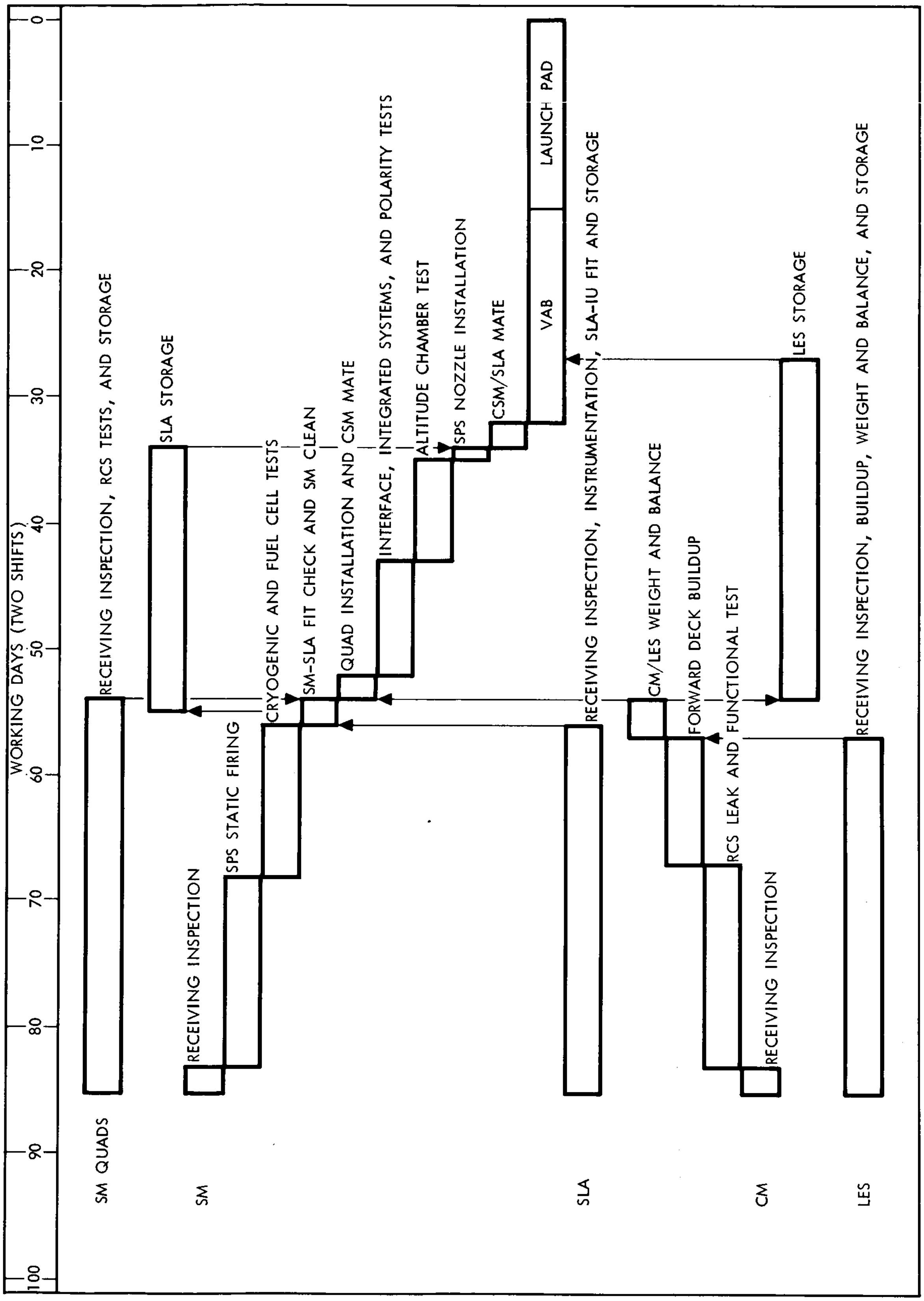


Figure 27. Field Operations Schedule for Heat Shield Reentry Test - Land-Landing System

[redacted]

[redacted]

DOWNEY TEST OPERATIONS

Flight spacecraft test operations at Downey provide acceptance checkout of the installed subsystems and integrated CSM spacecraft system. Check-out operations are designed to verify, within the limit of local safety ordnances, that the spacecraft system is physically and functionally capable of performing the assigned flight mission. The functional flow for Downey Test Operations is shown in Figure 28. The functions to be performed are summarized below in order to provide a basis for discussing impact of the Land Landing System. A preliminary schedule of these functions is shown in Figure 29.

DOWNEY OPERATIONS FUNCTION DESCRIPTION

LES/CM/SM Installed Systems Test

The objective of these tests is to demonstrate the functional capability of the SC systems by exercising them to their design limits. All system interfaces are verified except for fluid inter-connections between the CM and SM. The modules are installed on separate stands in the integrated test station. The CM is complete except for the aft heat shield. the ELS parachute system and ordnance devices. The SM is complete except for the High Gain Antenna (HGA) and SPS nozzle extension. The LES is complete except for the pyrotechnics, solid fuel motors, and Q-ball. The modules are mated together electrically by extender cables.

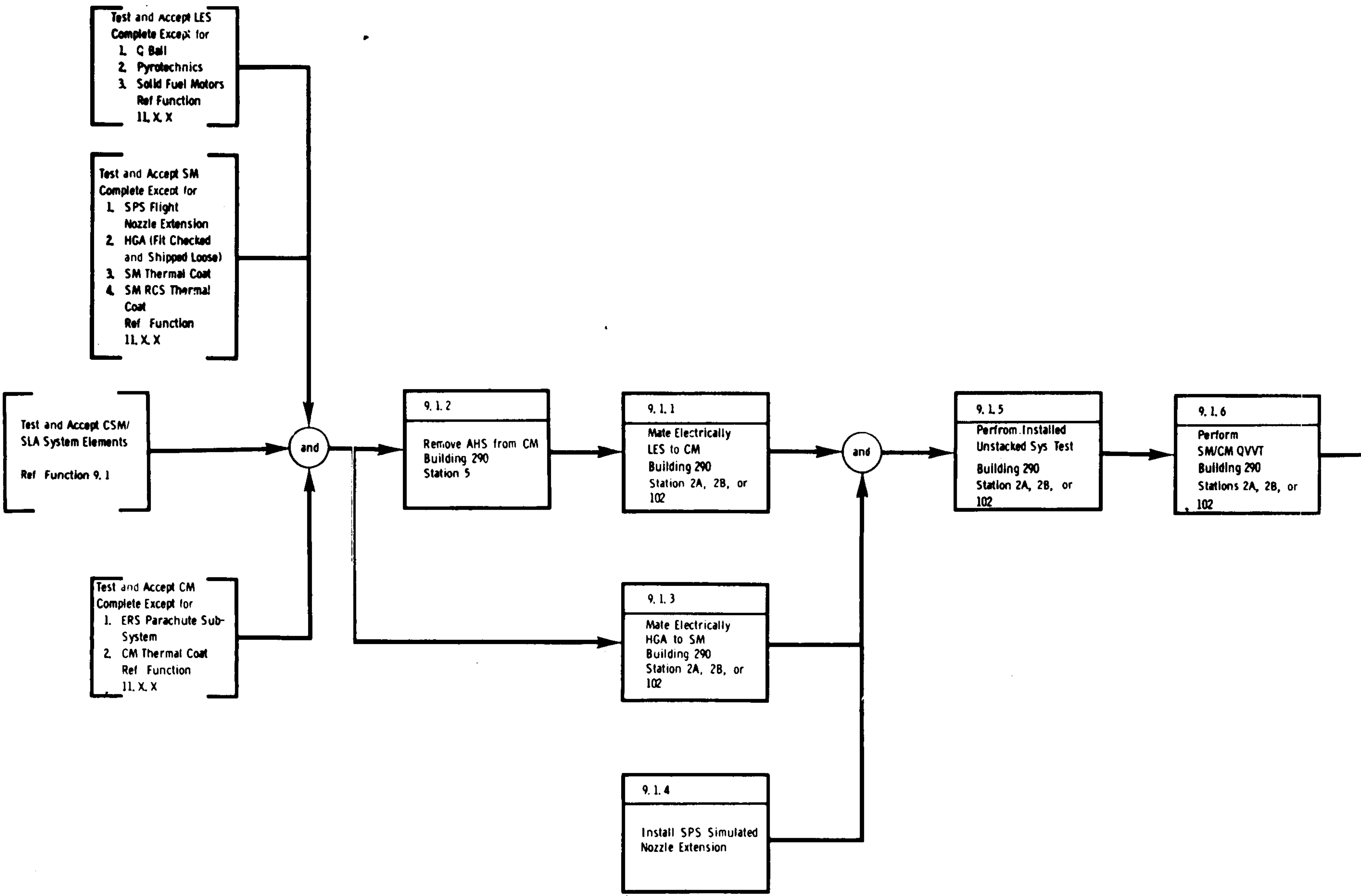
Functional checkout of the spacecraft begins with verifying the ECS water glycol system capability to provide cooling support to the subsystems. Checkout of the subsystems then follows a logical buildup from individual subsystem and combinations to an integrated system level. For example, the RCS subsystem, SCS and G&N are tested together following individual checkout.

The related Controls and Displays and instrumentation are verified at the same time as the subsystem. At conclusion of these tests, the spacecraft is verified ready for final integrated systems checkout.

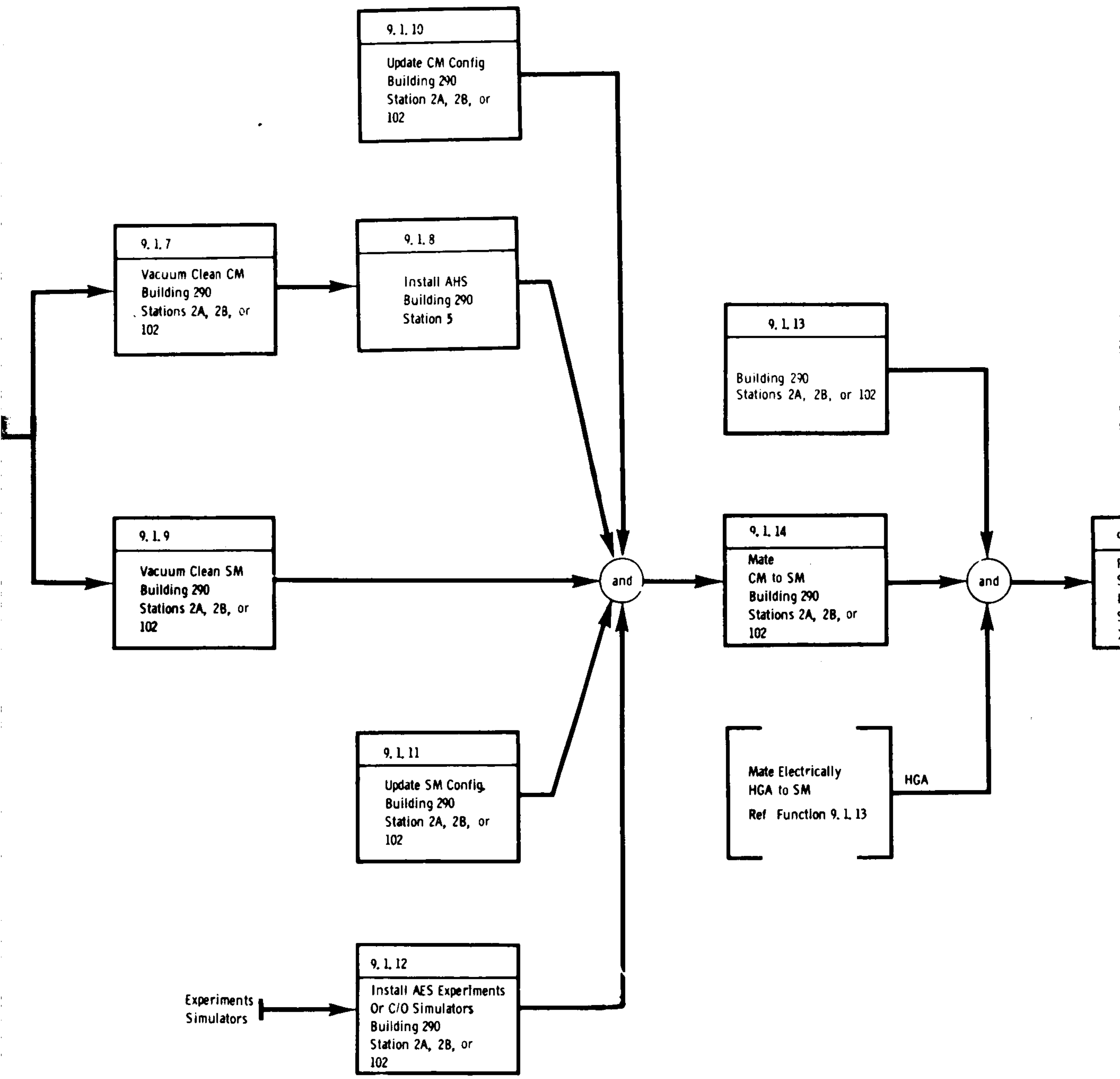
The land landing system, except for live ordnance, will be checked out as a subsystem and in combined test with interfacing subsystems such as the sequencer events control system.

Quality Verification Vibration Tests (QVVT)

QVVT is performed immediately following Installed Systems checkout, the spacecraft remains in the unstacked electrically-mated configuration. The subsystem operation is interrogated to verify satisfactory operation

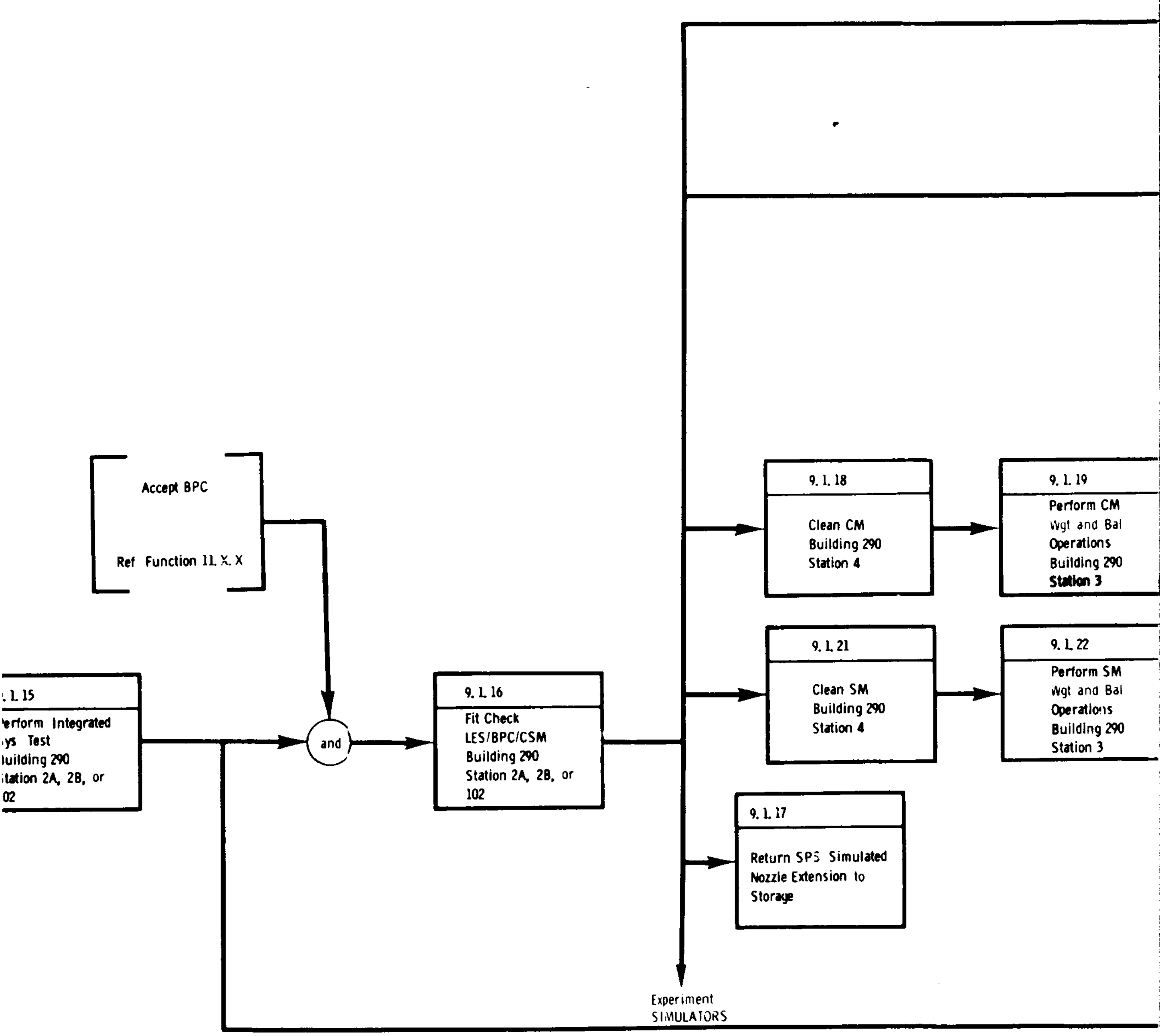

Test and Accept LES
Complete Except for
1. C Ball
2. Pyrotechnics
3. Solid Fuel Motors
Ref Function
11. X. X
Test and Accept SM
Complete Except for
1. SPS Flight
Nozzle Extension
2. HGA (Fit Checked
and Shipped Loose)
3. SM Thermal Coat
4. SM RCS Thermal
Coat
Ref Function
11. X. X
Test and Accept CSM/
SLA System Elements
Ref Function 9. 1
Test and Accept CM
Complete Except for
1. ERS Parachute Sub-
System
2. CM Thermal Coat
Ref Function
11. X. X
and
9. 1. 2
Remove AHS from CM
Building 290
Station 5
9. 1. 1
Mate Electrically
LES to CM
Building 290
Station 2A, 2B, or
102
9. 1. 3
Mate Electrically
HGA to SM
Building 290
Station 2A, 2B, or
102
9. 1. 4
Install SPS Simulated
Nozzle Extension
and
9. 1. 5
Perfrom Installed
Unstacked Sys Test
Building 290
Station 2A, 2B, or
102
9. 1. 6
Perform
SM/CM QVVT
Building 290
Stations 2A, 2B, or
102

FOLD-OUT #1

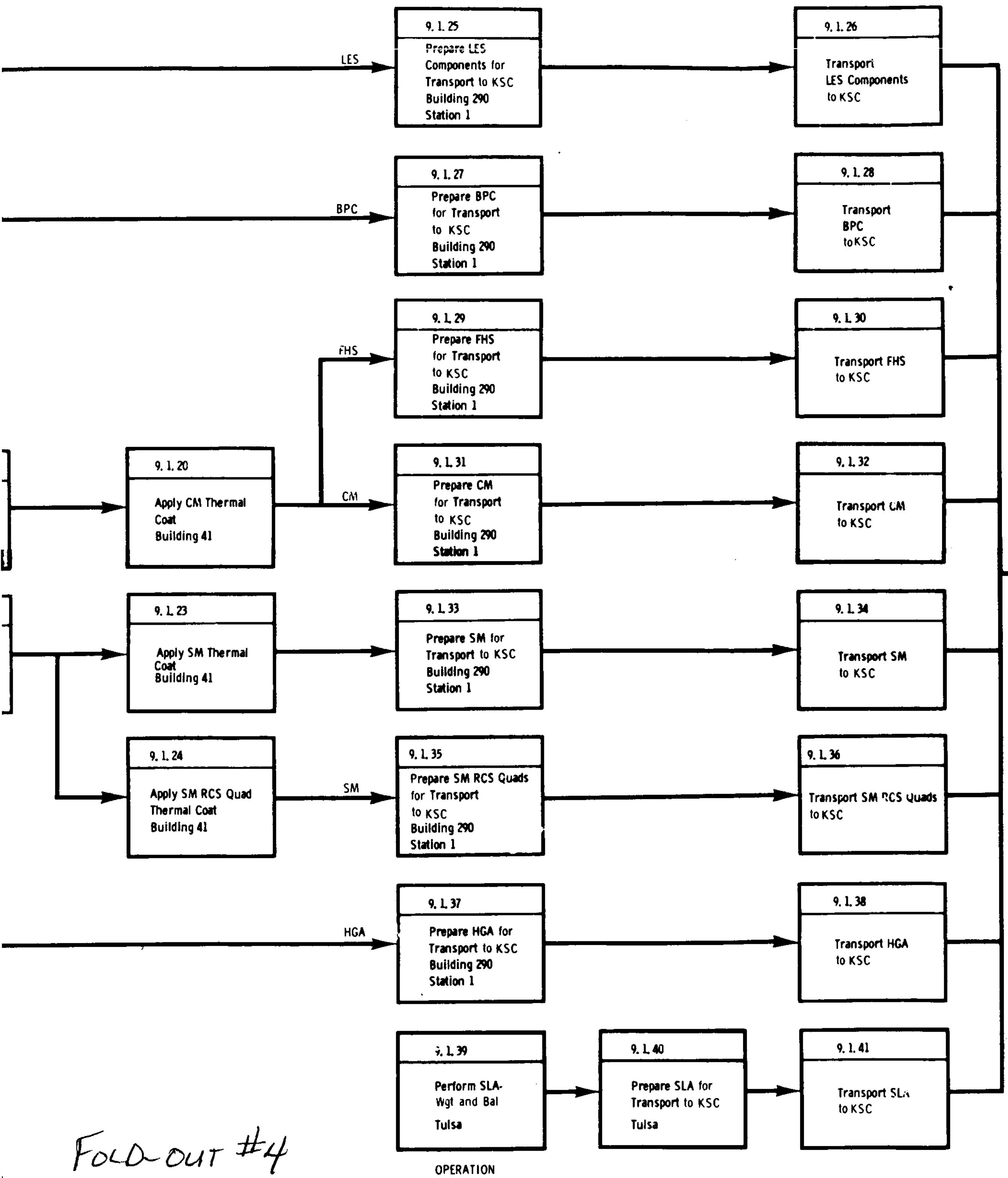


9. 1. 10
Update CM Config
Building 290
Station 2A, 2B, or
102
9. 1. 7
Vacuum Clean CM
Building 290
Stations 2A, 2B, or
102
9. 1. 8
Install AHS
Building 290
Station 5
9. 1. 13
Building 290
Stations 2A, 2B, or 102
9. 1. 9
Vacuum Clean SM
Building 290
Stations 2A, 2B, or
102
and
9. 1. 14
Mate
CM to SM
Building 290
Stations 2A, 2B, or
102
and
9. 1. 11
Update SM Config
Building 290
Station 2A, 2B, or
102
Mate Electrically
HGA to SM
Ref Function 9. 1. 13
HGA
Experiments
Simulators
9. 1. 12
Install AES Experiments
Or C/O Simulators
Building 290
Station 2A, 2B, or
102

FOLD-OUT #2


Accept BPC
Ref Function 11. X. X
. 1. 15
erform Integrated
ys Test
uilding 290
tation 2A, 2B, or
02
and
9. 1. 16
Fit Check
LES/BPC/CSM
Building 290
Station 2A, 2B, or
102
9. 1. 18
Clean CM
Building 290
Station 4
9. 1. 19
Perform CM
Wgt and Bal
Operations
Building 290
Station 3
9. 1. 21
Clean SM
Building 290
Station 4
9. 1. 22
Perform SM
Wgt and Bal
Operations
Building 290
Station 3
9. 1. 17
Return SPS Simulated
Nozzle Extension to
Storage
Experiment
SIMULATORS

FOLD-OUT #3



FOLD-OUT #4

Figure 28. Se

LEGEND

Command and Service Module Functions and Support Functions

[ ] Reference Function

ABBREVIATIONS

AHS	Aft Heat Shield
BPC	Boost Protective Cover
CM	Command Module
CSM	Mated Command and Service Module
FHS	Forward HeatShield
KSC	Kennedy Space Center, Florida
HGA	High Gain Antenna
LES	Launch Escape System
QVVT	Qualification Vibration Validation Test
RCS	Reaction Control System
SLA	Spacecraft/LEM Adapter
SM	Service Module

NOTES

AES Experiment Requirements to be Determined.

This Drawing is Based on AES Flight Mission Planning Data as Follows:

LV Configuration	S-IB
SC Configuration	CSM Only

→ 8.1
Deploy and Check-out CSM/Elements KSC Operations

FOLD-OUT #5

cond-Level Functional Flow 9.1, Test and Accept CSM System Elements

[redacted]

[redacted]

FUNCTIONS*	OPERATION	STATION
9.1.1, 3, 4	1. INSTALL CSM IN STATION 2 - CABLE UP	2**
9.1.5	2. CSM/STATION VERIFICATION	↓
9.1.5	3. ELECTRICAL POWER SYSTEM	
9.1.5	4. ENVIRONMENTAL CONTROL SYSTEM	
9.1.5	5. COMMUNICATIONS SYSTEM	
9.1.5	6. INSTRUMENTATION SYSTEM	
9.1.5	7. REACTION CONTROL SYSTEM	
9.1.5	8. SERVICE PROPULSION SYSTEM	
9.1.5	9. STABILIZATION AND CONTROL SYSTEM	
9.1.5	10. GUIDANCE AND NAVIGATION SYSTEM	
9.1.5	11. SEQUENCE AND EVENTS CONTROL SYSTEM	
9.1.5	12. SC5-6 & N-RC5-SPS COMBINED	
9.1.5	13. SPS FREQUENCY RESPONSE	
9.1.6	14. QVVT (SPS ABORT)	↓
9.1.7,9	15. CLEAN CM, SM	2
9.1.8	16. MOVE TO STATION 5 - INSTALL AFT HEAT SHIELD	5
9.1.14, 13	17. MATE CSM - INSTALL ACE CARRY ON-CABLE UP	2
9.1.12	18. INSTALL EXPERIMENTS AND/OR SIMULATORS	↑
9.1.10, 11	19. UPDATE CONFIGURATION	
9.1.15	20. CSM STATION REVERIFICATION	
9.1.15	21. CSM SYSTEMS REVERIFICATION AND EXPERIMENT CHECK-OUT	
9.1.15	22. PAD ABORT SIMULATION	
9.1.15	23. MEDIUM ALTITUDE ABORT SIMULATION	
9.1.15	24. HIGH ALTITUDE ABORT SIMULATION	
9.1.15	25. SPS ABORT SIMULATION	
9.1.15	26. MISSION SIMULATION - PLUGS IN	
9.1.15	27. SERVICE AND ACTIVATE FUEL CELLS	
9.1.15	28. MISSION SIMULATION - PLUGS OUT	
	29. DATA REVIEW AND CUSTOMER ACCEPTANCE READINESS REVIEW	
9.1.16	30. BOOST PROTECTIVE FIT CHECK	↓
	31. DEMATE CSM	2
9.1.18, 19, 20	32. CM TUMBLE AND CLEAN - WEIGHT AND BALANCE AND THERMAL COATING	3,4,B 41
9.1.25, 32	33. CM SHIPPING PREPARATION	1
9.1.21, 24	34. SM TUMBLE AND CLEAN - WEIGHT AND BALANCE AND THERMAL COATING	3,4,B 41
9.1.33, 38	35. SM SHIPPING PREPARATION	1

*REFERENCE: SID 65-1151 ** COULD BE STATION 2A, 2B, 2C, 101, OR 102

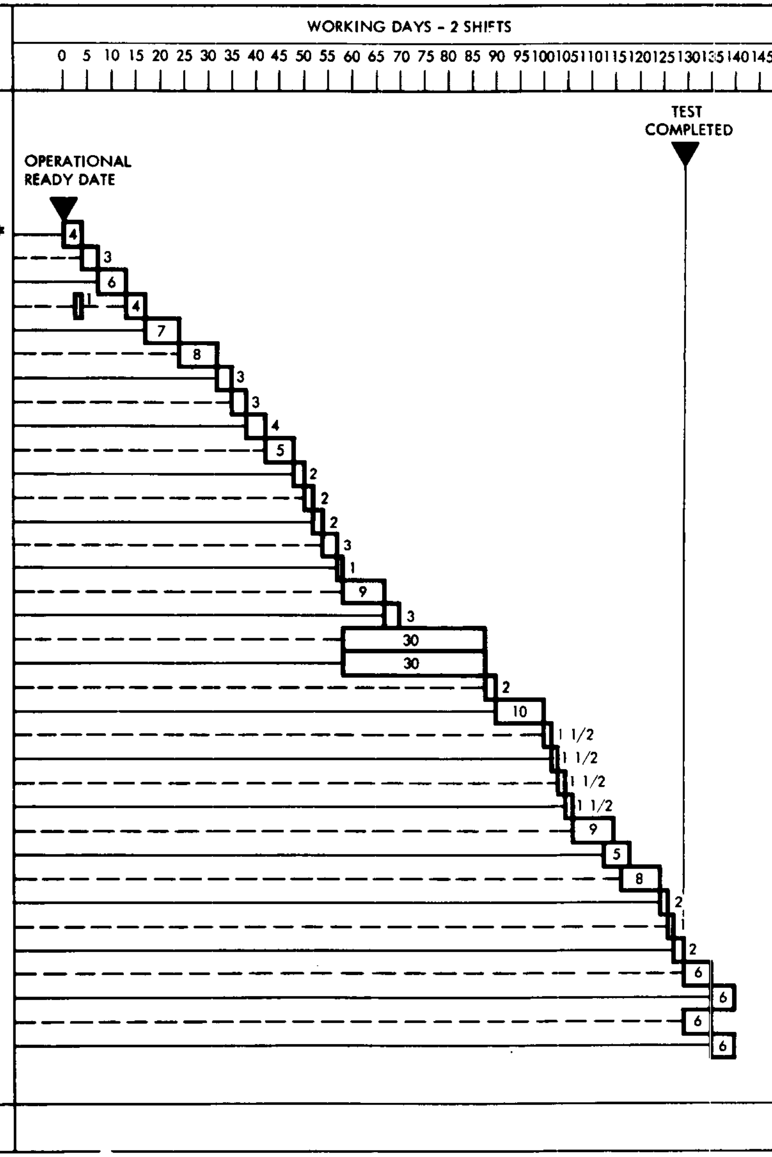


Figure 29. Preliminary AES Phase II Spacecraft Downey Operations Schedule

[redacted]

while the spacecraft is subjected to low-level vibration. The integrity of electrical connectors, solder joints, and mechanical mounts is verified.

Downstream CM and SM Configuration Update Period

The CM is moved to the heat shield installation station where the aft heat shield is installed preparatory to mating the CM and SM for integrated systems tests.

Outstanding Engineering Orders (EO's) or late equipment are incorporated in the CM and SM prior to CSM mating. The objective is to prepare the spacecraft for the final mission readiness verification during integrated systems tests. The configuration must be brought to that specified in the End Item Specification, including late EO's.

CM and SM Mating

The CM and SM are electrically and mechanically mated. The LES is electrically mated to the CM. The CSM, GSE and ACE-SC are prepared for integrated system tests.

Integrated System Tests

This test serves as a basis for spacecraft acceptance (DD250 sell off). Following mating, the CSM to checkout station (supporting GSE and ACE-SC) are re-verified as are the spacecraft subsystems. Changes or equipment incorporated during the configuration update period will be given a complete functional checkout before start of the actual integrated systems checkout.

The Integrated Systems checkout consists of end-to-end testing of the complete spacecraft systems while being operated in simulated mission modes. Test sequences will include all abort modes, countdown simulation. and flight mission simulation. The flight mission simulation. duplicates the flight operations sequences. but not necessarily in real time. Both plugs-in and plugs-out tests are performed. The latter is performed on fuel cell power with a substitute flight crew to allow disconnect from ground systems.

CM and SM Cleaning

The modules are individually cleaned to remove all foreign material. This is performed by rotating (tumbling) the module in the cleaning positioner to dislodge particles so that they may be removed by vacuum process.

Weight and Balance

The CM and SM are separately weighed to verify the weight and center of gravity to be within specified limits. Both horizontal and vertical checks are performed.

Mass simulators are used to support weight and balance operations in lieu of equipment designated for field installation.

Apply CSM Thermal Coat

The thermal coat is applied to the CM and SM just prior to preparing for shipment.

Preparation for Shipment

The spacecraft elements are preserved and packaged for shipment to KSC.

VARIATIONS IN DOWNEY TEST OPERATIONS

Configuration I

The effort added by Configuration I over the Block II ELS is minimal. It will require preparation of revised and new checkout procedures for installed systems test of the recovery system, QVVT and integrated systems test. Checkout of new or modified GSE will require new Operational Checkout Procedures.

Installed systems test requirements for Configuration I compared to the Block II system, adds checkout of the swivel steering, landing retro-rocket ignition circuit and altitude sensing probe, swivel steering control and added events sequencing.

Configuration II

Installed systems test for Configuration II will verify functional performance of the radar and infra-red altitude sensing systems, the steering control system, closed loop TV, heat shield plug thruster circuits, retro-rocket ignition circuits and events sequencing. This is a significant change from the Block II ELS. New and revised Operational Checkout Procedures and increased operations times result in slight increase to checkout time and manpower requirements. There is, however, minimal schedule impact on overall spacecraft Downey operations.

Configuration III

Test operation variations are identical to those for Configuration II.

Configuration IV

Variations from Block II essentially the same as for Configurations II and III. Operation and alignment checkout requirements for the fold out door which supports the altitude sensing elements will impose more requirements than the heat shield plug thruster system used in Configurations II and III.

Checkout of the retro-rocket ignition initiation signal will be essentially identical for 1 versus 4 solid motors. The rocket motor retaining device and release guide rail will be checked.

Variations from the Block II system test operations includes preparation of new and revised checkout procedures and additional checkout operations effort.

KSC OPERATIONS

Flight spacecraft test operations at KSC include the spacecraft pre-launch checkout functional flow shown in Figure 30, and the Space Vehicle launch complex operations. The Land Landing System will not affect the latter except for pyrotechnic initiator installation requirements. Therefore, only the spacecraft pre-launch operations functions are summarized below as a basis for discussion of the Land Landing System impact. A preliminary schedule of these operations is shown in Figure 31.

Field operations for the Land Landing system will include installation of live ordnance (retro-motors, parachute system mortars and pyrotechnics) and support of integrated systems tests.

CSM PRELAUNCH FUNCTION DESCRIPTION

SPS Static Firing Tests

Tests are performed to verify flight readiness of the complete service propulsion system. Leak and functional tests are performed including a live firing.

Fuel Cell and Cryogenic Systems Tests

Leak and functional test of the fuel cell and cryogenic systems are performed in the Fuel Cell System Test Facility (sometimes referred to as the Cryogenic Test Building). The SM is moved to the FCSTF after completion of the SPS static firing tests. Pressure and leak tests are performed on the EDS and the fuel cells are operated to verify functional performance.

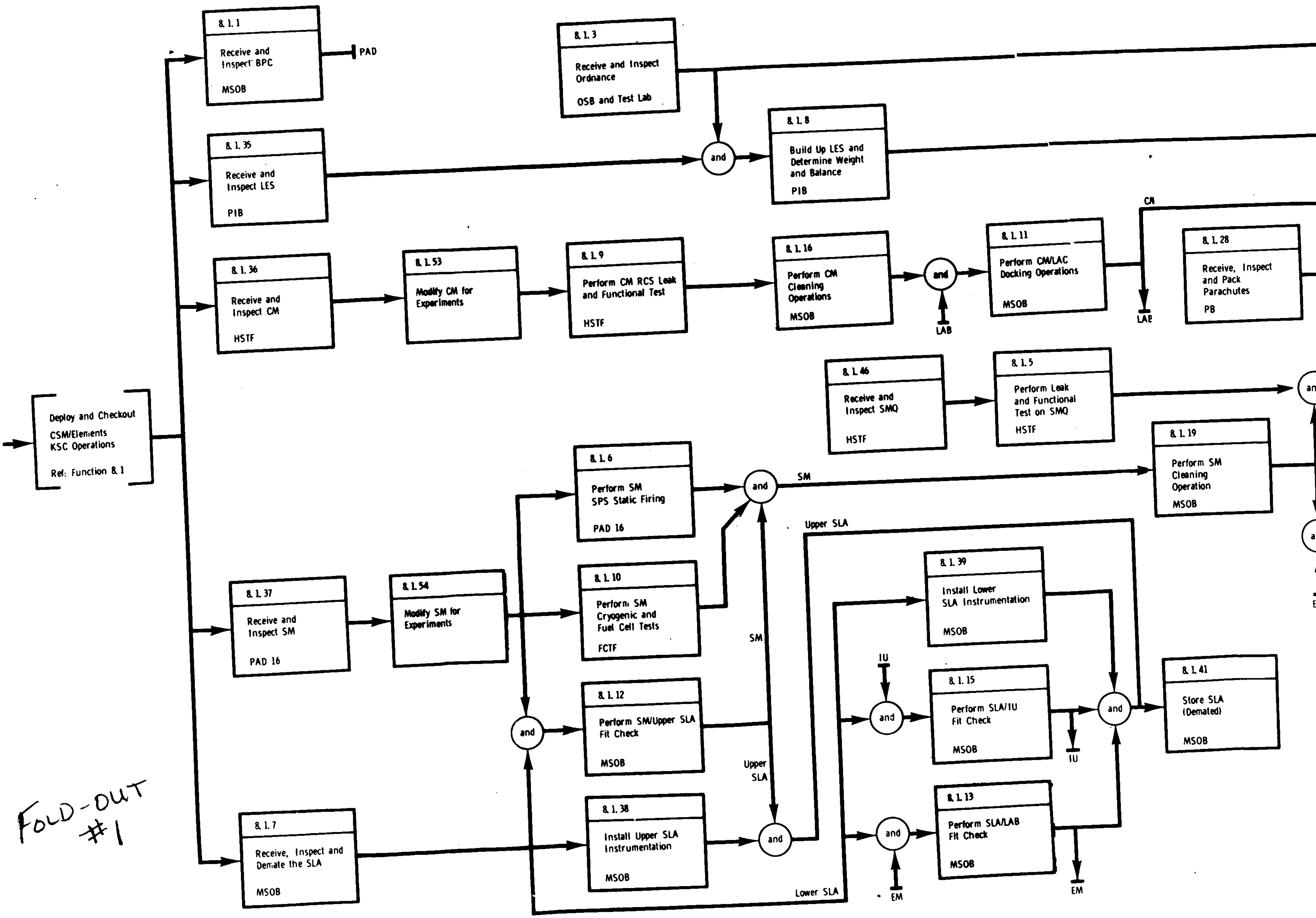
RCS Leak and Functional Tests

The CM and the SM Quads undergo RCS tests in the Hypergolic Test Facility. Since these tests are run concurrently, both cells of the HTB are utilized. Pressure and leak tests are performed using helium. Proper functioning of valves and regulators are verified and engine valve signatures are determined. The CM is moved to the MSOB upon completion of these tests. The SM Quads are stored until installation.

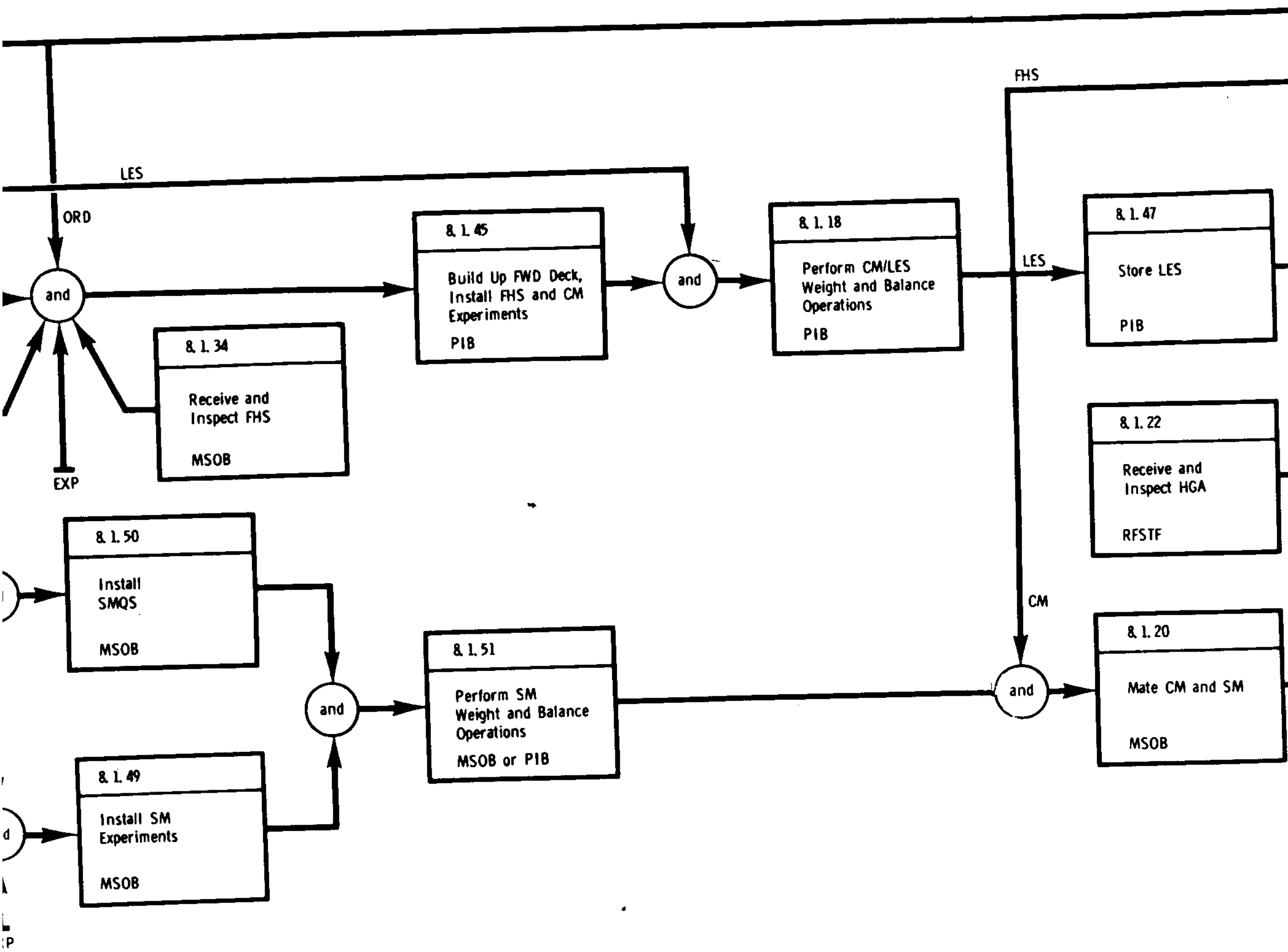
SM Weight and Balance

Upon completion of the field experiments installation, the RCS quads are installed and a weight and balance check performed on the SM. The weight and balance fixture is located in the pyrotechnic installation building. Both a horizontal and vertical weight operation is performed to establish the center of gravity.

DENTIAL



FOLD-OUT #1


LES
ORD
FHS
and
8.1.45
Build Up FWD Deck, Install FHS and CM Experiments
PIB
and
8.1.18
Perform CM/LES Weight and Balance Operations
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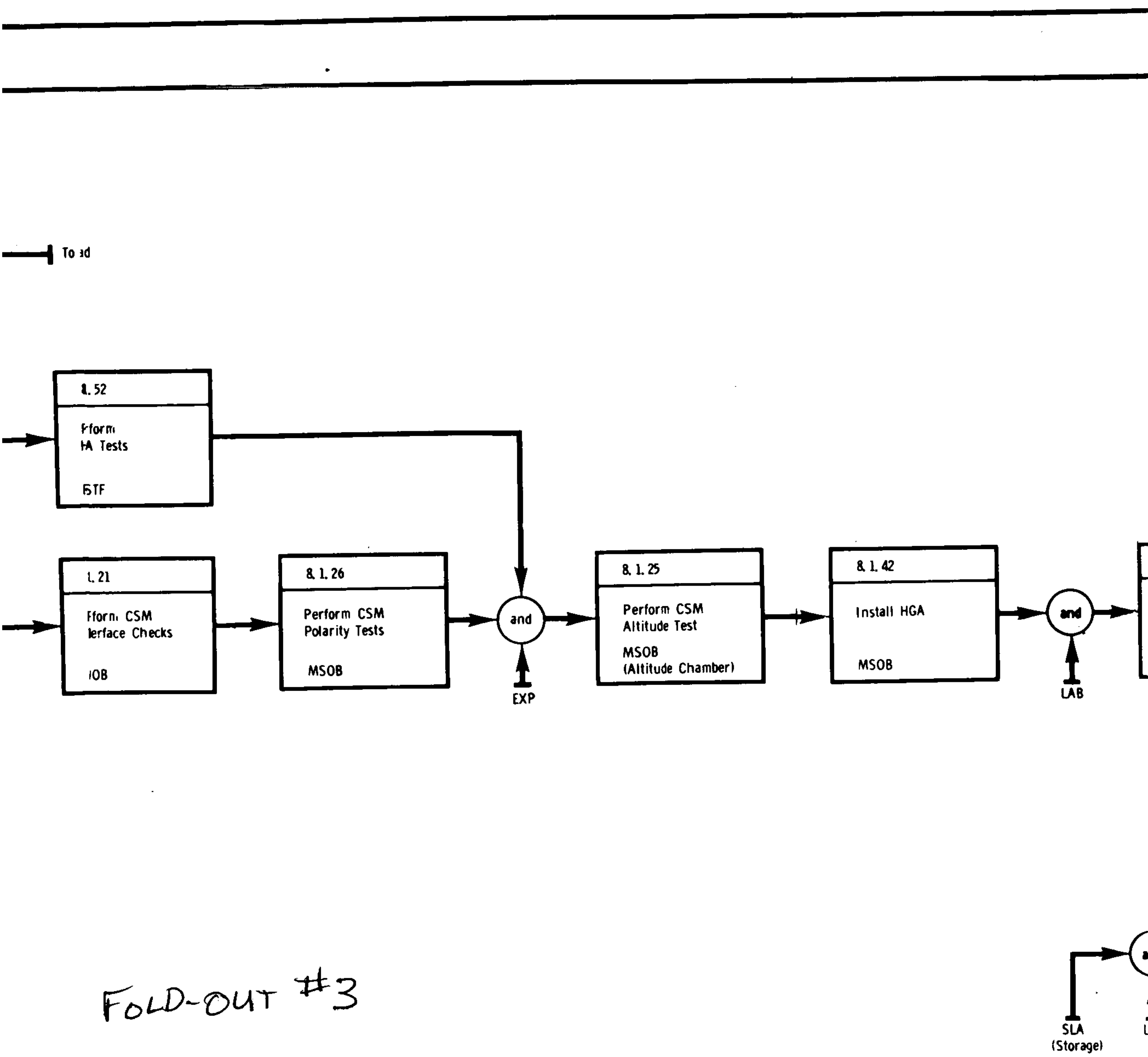
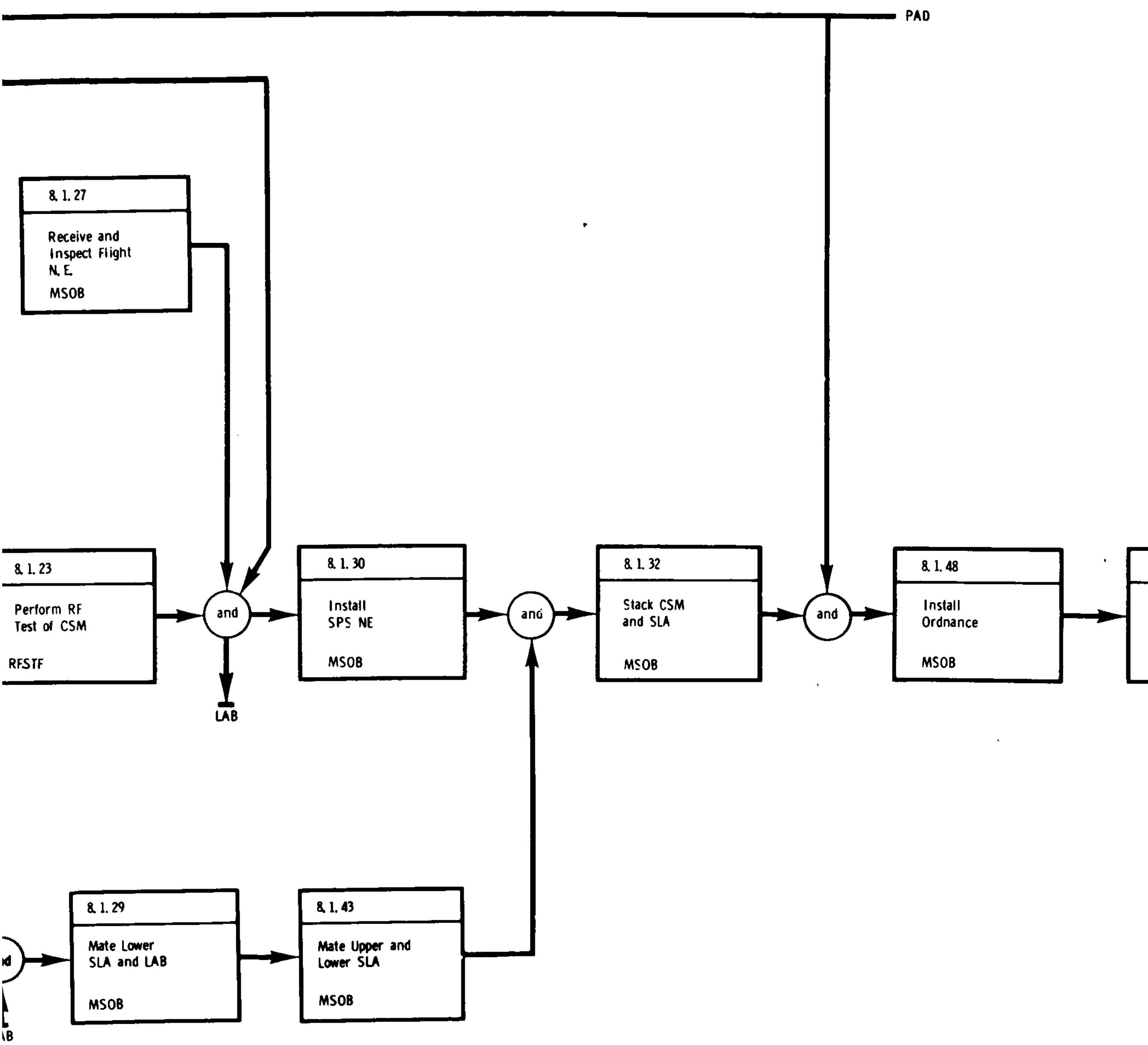
LES
8.1.47
Store LES
PIB
8.1.34
Receive and Inspect FHS
MSOB
EXP
8.1.22
Receive and Inspect HGA
RFSTF
8.1.50
Install SMQS
MSOB
CM
and
8.1.51
Perform SM Weight and Balance Operations
MSOB or PIB
and
8.1.20
Mate CM and SM
MSOB
8.1.49
Install SM Experiments
MSOB

FOLD-OUT #2


To ıd
ı. 52
Fform
ΗA Tests
ΒTF
ı. 21
Fform CSM
ıerface Checks
ΙOB
8. 1. 26
Perform CSM
Polarity Tests
MSOB
and
EXP
8. 1. 25
Perform CSM
Altitude Test
MSOB
(Altitude Chamber)
8. 1. 42
Install HGA
MSOB
and
LAB
SLA
(Storage)

FOLD-OUT #3



FOLD-OUT #4

Figure 30. S

LEGEND

Command and Service Module Functions and Support Functions

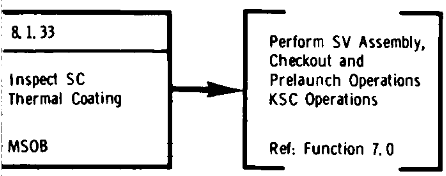
Reference Functions

FACILITY ABBREVIATIONS

OSB . . . . Ordnance Storage Building
PIB . . . . Pyrotechnic Installation Building
HSTF. . . . Hypergolic System Test Facility
PAD 16. . . Propulsion Test Complex (Pad 16)
MSOB . . . Manned Spacecraft Operations Building
RFSTF . . . RF System Test Facility
PB. . . . . Parachute Building
FCTF . . . . Fuel Cell Systems Test Facility

VEHICLE ABBREVIATIONS

LES. . . . . Launch Escape System
FHS . . . . Forward Heat Shield
CM . . . . Command Module
SMQ . . . . SM Quads
SM . . . . Service Module
SLA . . . . SC/LEM Adapter
SPS . . . . Service Propulsion System
SC. . . . . Spacecraft
RCS . . . . Reaction Control System
HGA . . . . High Gain Antenna
CSM . . . . CM and SM
IU . . . . . Instrument Unit
NE . . . . . Nozzle Extension



FOLD-OUT #5

econd-Level Functional Flow 8.1 Deploy and Checkout CSM Elements

[redacted]

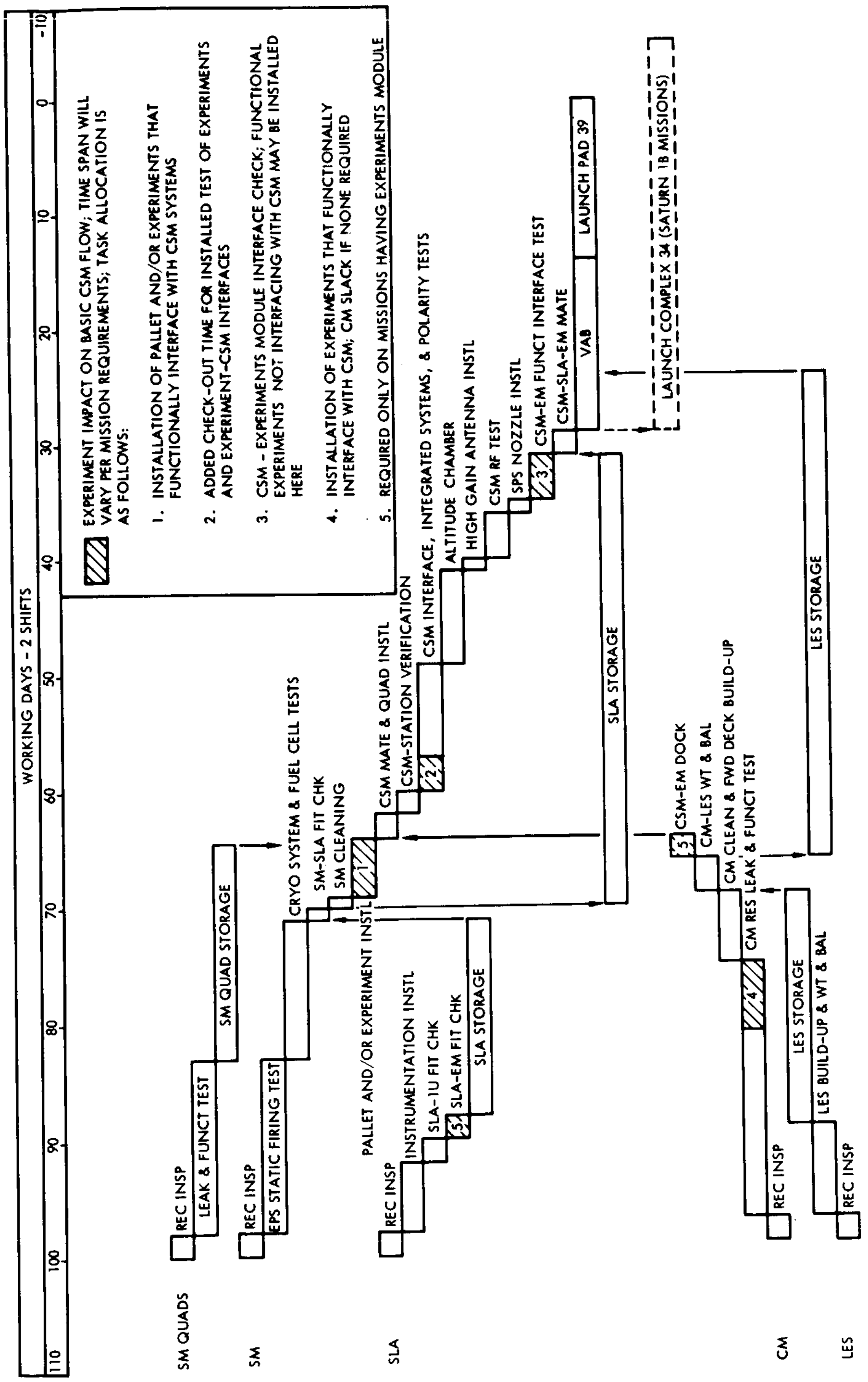


Figure 31. Preliminary KSC Typical AES CSM Operations Flow

CM Experiment Installation and Top Deck Buildup

The CM experiment installation and top deck buildup may be partially performed concurrently. The CM is positioned in the MSOB or equivalent clean room environment for the experiment installation. The EIS (or LIS) ordnance installation requires use of the PIB. The parachutes, ordnance, experiments and forward heat shield installations are completed before weight and balance.

CM-LEM Laboratory Docking Check

At the earliest point convenient to the LAB and CM operations flow, the two modules are fit checked in the docked configuration. The LAB ascent stage is lowered (inverted) at a simulated zero "g" condition until the capture latches of the CM probe engage the drogue. The probe is then retracted so that the ascent stage is lowered to a soft docked position. The ascent stage is pressurized to five psi before the modules are hard-latched. The probe and drogue are removed and stored in the CM. Tests include leak checks of the interface seal, circuit analyzer check of the electrical umbilical and crew sight alignment. The probe and drogue are reinstalled and delatching operations checked.

CM-LES Weight and Balance

A weight and balance check is made on the CM following experiment installation and forward deck buildup. The weight and vertical, lateral and longitudinal center of gravity are verified to be within specified tolerances. These tests are performed using the weight and balance fixtures in the PIB.

The LES, having previously undergone weight and balance checks, is mated to the CM in a vertical attitude. The CM-LES is then weighed, and the LES thrust vector alignment checked.

The Land Landing System elements must be installed prior to this test. The live retro motors may be removed subsequently and reinstalled prior to pad operations.

Mate CM and SM

The SM is positioned on the polarity fixture in the integrated test stand (Stokes #2). The CM is mated to SM and alignment of the mated modules verified.

CSM - Station Cable Up and CSM Interface Verification

The first operation performed in the mated CSM in the integrated test station is the making and checking of the interface with all support equipment and facilities. The ACE-SC carry-on equipment is installed and all GSE connected. The spacecraft ECS is serviced and checked. Continuity and spacecraft systems control and monitor interface with ground systems are verified. The CSM electrical power distribution is also verified. The CM to SM interface connections are verified.

These tests are completed before initiation of functional checkout of spacecraft subsystems or experiments.

Installed Experiment Checkout

The individual experiments installed in the field are verified to function properly when installed in the CSM and as influenced by interfaces such as electrical power supplied from the CSM EPS. The experiments are, insofar as possible, manually operated. ACE-SC is used to monitor experiment output parameters and, if necessary, to supply stimuli to experiments. End-to-end tests are performed to verify that the experiment performs within specified limits and experiment measurements are properly transported and recorded by the supporting data collection and storage system. These tests are completed before initiating CSM integrated systems testing with experiments included.

CSM Integrated Systems and Polarity Tests

Integrated systems tests are performed to demonstrate operational performance capability of the integrated spacecraft subsystems, including experiments, during simulated abort and mission sequences. Polarity tests are performed to verify end-to-end phasing of the attitude control, thrust vector control and delta "V" flight subsystems.

During integrated systems tests, the subsystems are operated, as nearly as possible, in the modes and input sequences of the phase of mission being simulated. Response of each of the subsystems are monitored to verify the correct timing and sequence of operation. Test sequences are run for each abort mode. The mission simulation includes all sequences, and redundant modes or systems, from countdown through earth recovery. The systems are operated from the CM controls. Experiment functions are integrated with the spacecraft systems operation in the normal flight sequence.

The polarity test is performed by providing rotational inputs from the polarity fixture. The end-to-end polarity of the thrust vector control loop is verified.

The Land Landing System is operated and verified during the integrated system test. A recovery sequence is performed during these tests.

Altitude Test

The altitude tests, performed in the chamber in the MSOB, are made to verify spacecraft operation at altitude. The CSM is manned by three astronauts and altitude runs are performed at 250,000 feet. ECS, fuel cell operation and structural integrity are verified. The spacecraft radiators, evaporators, and cold plates provide the temperature characteristics of the water-glycol of the ECS, and fuel cells structure leak rate is determined. Simulated flight sequences will be made to verify systems operation at altitude. Experiment operation and environmental control will be demonstrated under the 250,000 foot altitude and cold plate environment of the chamber.

The Land Landing system will be monitored for stray inadvertant signals during altitude operation.

CSM RF Systems Test

Tests are performed to verify operation of the CSM RF systems. Voltage standing wave ratio (VSWR) checks are made on all antennae including experiment data transmitting systems. Telecommunications systems output frequency and power are measured. The high gain antenna (HGA) is installed and boresighted. A functional check is performed on the X-band transponder. Uplink reception is measured. System performance and absence of adverse interaction between the various RF systems is demonstrated.

The CSM RF test may be conducted in combined RF test with the LEM mission module.

Although the CSM RF tests could be implemented in the MSOB, use of the RFSTF and combined docked test with the LAB would enhance checkout. Requirements for RF and EMC test of the CSM-LAB interfaces requires further analysis before the test operations can be fully defined.

The Land Landing System is involved in this test only in the verification of the absence of stray signals.

CSM Interface Test

Electrical interfaces between the CSM and Laboratory are tested. A docked compatibility test may be required, especially if there is an exchange of electrical power. This test is currently defined as a simulated docked configuration (cable connected) test.

The Land Landing System circuits will be monitored for stray signals during this test.

Stack CSM-SLA-LAB

The LAB is mated to the lower SLA in the Stokes stand #2. The spacecraft to LV separation circuit is given an end-to-end check by cable connection from the CSM on an adjacent stand. The upper SLA and CSM are then mated to the lower SLA/LAB modules. The stacked spacecraft is then ready for mating with the launch vehicle.

Install Ordnance Devices

All electro-explosive devices are installed before moving to the launch complex. The Land Landing System ordnance elements, including retros not installed permanently during top deck build-up will be installed. Initiators and igniters are installed at the launch pad.

VARIATIONS IN KSC TEST OPERATIONS

Configuration I

Checkout effort for Configuration I is slightly greater than for the Block II ELS and increases the installation effort associated with the landing retro-rocket system. New and revised procedures must be prepared reflecting changes from the Block II system. The swivel steering and retro-rocket system adds to the checkout and GSE requirements. Installation of the heat shield plugs, thrusters and rocket motors are planned as field effort.

The Land Landing system checkout at KSC will be interrogation during integrated systems testing, altitude chamber test, CSM RF test, and CSM-LEM Mission Module Compatibility test. Verification is necessary of all pyrotechnic circuits before electroexplosive devices are installed during top deck build-up and ordnance installation periods. Final checks are performed before initiator or igniter installation.

Configuration II

Configuration II adds to the field manpower and GSE when compared to the Block II ELS requirements. Additional installation tasks associated with the landing retro-rocket system and checkout of the steering, altitude sensing and retro-ignition, and closed loop tv subsystems are required. The addition of these LLS elements requires greater effort to update procedures from Block II to AES Phase II operations. The field checkout is primarily associated with subsystems in integrated system testing. However, the high resolution requirements of the altitude sensing and tv systems indicates special requirements. The checkout of the sensing elements may pose a problem because of location in the aft compartment. The heat shield must be closed out before mating at launch minus 3 months. Subsequent testing in the area must be provisioned through the side access door.

New GSE will be required to support Configuration II. Modifications to existing GSE will also be required because of interface differences from the Block II system. For example, the input stimuli signal quantity and checkout measurements increase, causing a change to the ACE-SC signal conditioner equipment. Top deck build-up effort does not change significantly. However, installation of the heat shield plugs, thrusters, and retro-rockets is an added requirement compared with the Block II system requirements.

Heat Shield plugs, thrusters, and rocket motors will be installed prior to CM/LES weight and balance. If safety practice requires, the motors may then be removed until just before launch pad operations, at which time all SC ordnance is installed except initiators and igniters.

Configuration III

Test operations required for Configuration III are identical to those for Configuration II.

Configuration IV

Configuration IV has essentially the same impact on the field effort as does Configurations II and III, although operations are slightly different.

Rocket motors will be installed during the top deck build-up.

Additional checkout requirements involve the retro-rocket ignition altitude sensing systems, parachute steering control, closed loop TV system and fold out sensor support door. The radar altimeter and infra-red altimeter sensors are accessible throughout pre-launch operations. Although not yet defined in detail, checkout requirements for these system elements are anticipated in addition to the total LLS in the integrated systems tests. This deviation from normal field practice will be due to the high resolution and crew safety considerations applicable to the altitude sensing systems.

[redacted]

LOGISTICS

Logistics support analyses were performed for the LLS configurations. Logistic functions, such as site activation, maintenance (including modification), technical documentation, training, support (transportation, packaging, handling, and storage), maintainability (maintenance analysis), and supply support (spares), were reviewed for the specific requirements of each configuration.

It was assumed that the LLS modifications to the CSM will be accomplished inline and only minor support operations pertaining to interfacing of components, e.g., electrical connections, servicing, testing, calibration, parachute installation, etc., will be accomplished at the NAA/NASA test sites such as El Centro, WSMR, MSC, or KSC.

Recovery support required for ground and flight operation is assumed to be furnished by NASA, DOD, etc. This includes aircraft, ships, etc., and the supporting equipment and personnel required. NAA would be responsible for the CSM and associated hardware and equipment, except GFP, which would be NAA managed, in most instances.

Existing Apollo storage and warehousing facilities, such as the KSC environmental storage facility, are assumed to be adequate and available to accommodate the LLS program. Basic Apollo facilities/GSE Site Activation Plans, SID 64-826, and existing subordinate documentation would be applicable.

REQUIREMENTS ANALYSIS

Each proposed LLS component/subsystem was grossly analyzed for its effect on specific AES logistics support areas. These support requirement considerations are presented in the AES LLS Support Requirement Summary, Tables 3 through 6. Each item (component or subsystem) was reviewed initially as a new (N) or modified (M) addition to the Block II Earth Recovery System (ERS). New LLS items will require inputs to all logistics plans and requirements developed for AES Phase II, (except for field modification) whereas the AES modified items will require only minimum changes. For example, in most cases, technical documentation (support plans, operations and maintenance instructions, etc.) would have to be revised to reflect the status and operation of the modified items. New items will require support analysis to be performed to determine the specific impact on logistics functions.

TECHNICAL DOCUMENTATION

In the analyses of LLS impact on existing technical documentation for all configurations the following documents were considered:

Recovery Operations Handbook

RCS Deactivation Procedures for Handling and Safing Teams

[redacted]

[redacted]

Ground Support Equipment Operational Checkout Procedures

Illustrated Parts Breakdown

Calibration and Proofloading Data Handbook

Ground Support Equipment Catalogue

Apollo Operations Handbook CSM

Familiarization Handbook

GSE Operations, Service, and Maintenance

MAINTENANCE AND MODIFICATION

Maintenance

Procedures as outlined in the Apollo Maintenance Plan, SID 62-702-2, will be applicable for the maintenance required for the LLS. Maintenance as anticipated for specific LLS items are denoted in the AES LLS Support Requirement Summary Tables 3 through 6.

Ground Support Equipment Modification

A modification is considered to be a change in the design of an end item to meet operational requirements of LLS program. Modifications within the context of this plan will encompass changes authorized by the NASA after the execution of an inspection and acceptance of record, using a Form DD-250. Modification kits for the GSE and spares will be furnished by NAA in accordance with existing procedures. This system contains the management controls necessary for authorizing the fabrication or procurement of modification kits to meet specific contractual requirements. NAA's kit program includes provisioning, warehousing, accumulating for shipment, and installation of kits at NAA or the NASA test and operational sites. When unique or special subcontractor/supplier equipment and/or techniques are required, NAA will coordinate with the subcontractor/supplier and the NASA, as required, to facilitate modification with the least amount of program impact.

TRAINING

It will be NAA's responsibility to provide all levels of LLS training on the hardware and software items under the Contractor's jurisdiction. This will include the training of NASA personnel as well as the Contractor's, and to provide this training in the most efficient, economical way, on schedule. Personnel affected will include the NASA ground operations, and flight crew, contractor and associated subcontractor/supplier personnel, as applicable. LLS training requirements are denoted in the "AES LLS Support Requirements Summary Tables 3, 4, 5, and 6, for Configurations I through IV, respectively. Utilization of existing NAA, subcontractor/supplier and NASA training data, facilities, personnel, aids, simulators, etc., to the maximum extent is a prime requisite of each of the LLS configurations being considered in this study. All LLS training requirements and data will be incorporated, in phase, into existing training plans and course material. Changes to existing mission simulators and training devices will be accomplished.

SUPPORT (HANDLING, TRANSPORTATION, PACKAGING AND STORAGE)

Ground handling and transportation will require full design recognition of the durability requirements for the LLS components. Special packaging and transportation methods will be required to preserve LLS reliability.

LLS Configuration I through IV items that will be affected by support considerations are shown in the AES LLS Support Requirement Summary, Table 3, 4, 5, and 6, respectively. Generally speaking, existing Apollo procedures will be applicable for most of the support requirements, including the following:

1. Reefing line cutters, disconnects, riser cables are either dry film lubed or anodized, but spares packaging, handling and storaging may adversely affect these or like items if not accomplished according to proper specifications.

2. Operationally, parachutes will arrive at KSC specially packaged to seal against adverse environmental conditions and will not be unpacked until just prior to installation in the CM at the PIB at KSC.

3. Permanent degradation of pyrotechnic devices is both temperature and pressure dependent. Since sealed ordnance devices are used in the LLS, orbital storage pressures are not expected to cause significant degradation. However, because of finite leak rate and limited shelf life, environment facilities will be used at storage sites.

4. LLS materials and parts will be stored in a manner that will prevent intermixing, damage, corrosion, or contamination. Preserved items and age controlled materials will be issued from stock in a first-in, first-out basis. Critical and calibrated components items (baro-switches, parachutes, etc.) will be stored in a bonded and environmentally controlled area, as required. Identification and traceability controls of all items will be maintained. A preventative maintenance program will be in effect, and will support applicable specifications.

5. The Viton material used as seals in the drogue and pilot mortars, and the Neoprene seals used on the pressure cartridges and in the breech of the pilot mortar should be environmentally protected prior to installation to preclude jeopardization of shelf life.

[redacted]

MAINTAINABILITY

The LLS will be designed to ensure that maintenance and other support activities can be performed within the time-critical limitations established by operational requirements. During all stages of design and operation, accessibility for testing, inspecting, servicing, calibration, replacing or repairing all items will be considered.

The probable impact upon each item considered from a maintainability standpoint is shown in the "AES LLS Support Requirement Summary," Tables 3 through 6.

The maintenance requirements of the LLS items and supporting equipments will adhere to the Apollo based maintenance level concept as denoted in the "Apollo Maintenance Plan," SID 62-702-2, (A, B. and C levels).

Consideration was given to AES LLS maintainability requirements with respect to the Apollo lunar spacecraft configuration to eliminate interfacing problems by utilizing the basic Apollo vehicle with minimum changes for the LLS requirements, i.e., GSE and CSM systems and associated software and equipments.

SUPPLY SUPPORT

Each LLS configuration was analyzed to determine specific spare requirements (reference, AES LLS Support Requirements Summary, Tables 3, 4, 5, and 6). Spares will be provided to the following levels at the launch site and/or the Contractor's facilities, as applicable:

1. Electrical and electronic spares will be provisioned to the replaceable package (black box) level.

2. Mechanical spares will be provisioned to the lowest replaceable unit level, consistent with minimizing delays in field and factory test due to maintenance activities.

3. Ground Support Equipment spares will be provisioned to the lowest replaceable unit level, consistent with approved capabilities at test sites, the Contractor's facilities, NASA sites, and within cost restraints established by the NASA.

CONFIGURATION-DEPENDENT LOGISTICS VARIATIONS

The following paragraphs describe the specific variations for each LLS configuration as they affect the logistical elements, e.g., site activation (GSE requirements and modifications) and technical documentation.

CONFIGURATION I

Configuration I is defined as containing an Earth Recovery System (ERS) identical to the Apollo Block II ERS except for the addition of basemounted Gemini retrorockets and a controllable swivel "flowerpot." Specific requirements relative to logistical support planning are as follows:

<u>Site Activation</u>

New GSE is not required. However, the C14-452, ELS control electrical test stand will require an approximate 5% modification to accommodate changes in the ELS sequencer. AES program impact will be minor. Availability of GSE to be modified and possible confliction with other program schedules must be considered as a possible constraint.

<u>Technical Documentation</u>

The required changes for Configuration I will be the least of the four LLS configuration. From entry through main parachute disreef, the system is identical to Block II Apollo. New LLS items will include mirrors, controllable swivel, an impact attenuation system, use of an existing rotational hand controller and modification to other items. Approximately fifteen system modifications are anticipated (thirteen are considered minor and two are major changes). Provisions to incorporate the swivel will require approximately five changes, of which four are considered minor and one major,

The analysis of technical documentation requirements for specific Configuration I LLS items are shown in the AES LLS Support Requirements Summary Table 3.

CONFIGURATION II

Configuration II consists basically of a steerable Parasail main parachute with a Ringsail backup, basemounted retrorockets and supporting vision and sensing subsystems. Specific requirements in support of this configuration are as follows:

New GSE requirements are as follows:

a. Four sets of checkout GSE; one set each for Downey and MSC, and two sets for KSC. Exception: C34-ZZZ only requires 3 sets; one at each location.

b. Three sets of BME; one set each for Downey, MSC, and KSC.

Site Activation

New GSE models required will include: the C34-XXY, radar altimeter BME - to provide bench check capability of the altimeter "black boxes," the C34-XYY, ERS TV display checkout set - which will verify TV display resolution and sensitivity, and system alignment and drift meter function; the C34-ZYY ERS TV display BME - to provide bench check capability of the TV display "black boxes".

Installation of the new GSE will have a minimal program impact. Facility modification will include installation of GSE supporting cables (probably individual cables would be simplier and more economical rather than breaking into an existing conduit.)

Existing GSE requiring modification include the following:

a. H14-044, Parachute handling sling (15%)

b. C14-451, ELS Sequencer control pressure stimuli generator (10%)

c. C14-452, ELS Control electrical test stand (20%)

Technical Documentation

Technical data requirements for Configuration II will include approximately ten system changes (6 minor and 4 major) to the retro system, four changes to the sensing system (all considered minor), four changes to the vision system (all considered minor), and seven changes to the parachute system (six minor and one major change). All these changes or modifications will be accomplished at the contractors facility, except those normally accomplished at KSC, such as, installation of pyrotechnics and parachutes.

The analysis of technical documentation requirements for Configuration II LLS items are shown in the AES LLS Support Requirements Summary, Table 4.

CONFIGURATION III

Configuration III is defined as containing a steerable Cloverleaf parachute with a Ringsail parachute as backup. New basemounted retrorockets are also installed, together with a vision and sensing subsystem. Specific requirements for this configuration are as follows:

New GSE requirements are as follows:

a. Four sets of checkout GSE; one set each for Downey and MSC, and two sets for KSC. Exception: C34-ZZZ only requires 3 sets; one at each location.

b. Three sets of BME; one set each for Downey, MSC, and KSC.

[redacted]

Site Activation

New GSE models required will include: the C34-XXX, radar altimeter checkout set - to verify altitude rate and sensing functions; the C34-XXY, radar altimeter BME - to provide bench check capability of the altimeter "black boxes"; the C34-YYY, I.R. altimeter checkout set to verify altitude rate and sensing functions; the C34-YYX I.R. altimeter BME - to provide bench capability of the I.R. altimeter "black boxes"; the C34-XYY, ERS TV display checkout set - which will verify TV display resolution and sensitivity, and system alignment and drift meter function; the C34-XYY, ERS TV display BME - to provide bench check capability of the TV display "black boxes"; C34-ZZZ, ERS flight control system checkout set - to check control reel rates and travel on an end-to-end system basis; C34-ZZY, ERS flight control system BME - to provide a bench check capability for system components.

Installation of the new GSE will have minimal program impact. Facility modification will include installation of GSE supporting cables (probably individual cables would be simpler and more economical rather than breaking into an existing conduit.)

Existing GSE requiring modification include the following:

a. H14-044, Parachute handling sling (15%)
b. C14-451, ELS Sequencer control pressure stimuli generator (10%)
c. C14-452, ELS Control electrical test stand (20%)

Technical Documentation

Technical data requirements for Configuration III will include one minor change to the rotational hand controller, ten changes to the retro system, same changes as for Configuration II, six considered minor and four major. Four changes are anticipated for the sensing system, all minor.

The vision system will require four minor changes and the parachute system will incorporate seven changes, six minor and one major. All of these changes or modification will be accomplished at the contractor's facility, except those normally accomplished at KSC, such as, installation of pyrotechnics and parachutes.

The analysis of technical documentation requirements for configuration III LLS items are shown in the AES LLS Support Requirements Summary Table 5.

CONFIGURATION IV

Configuration IV is defined as containing a steerable Cloverleaf parachute with a Ringsail parachute as backup. The rocket configuration consists of a single motor stowed in the recovery compartment which is deployed in a riser-suspended configuration, together with vision and sensing subsystems.

[redacted]

Specific requirements for Configuration IV are:

New GSE requirements are as follows:

a. Four sets of checkout GSE; one set each for Downey and MSC, and two sets for KSC. Exception: C34-ZZZ only requires 3 sets; one at each location.

b. Three sets of BME; one set each for Downey, MSC, and KSC.

Site Activation

New GSE models required will include: the C34-XXX, radar altimeter checkout set - to verify altitude rate and sensing functions; the C34-XXY, radar altimeter BME - to provide bench check capability of the altimeter "black boxes"; the C34-YYY, I.R. altimeter checkout set to verify bench capability of the I.R. Altimeter "black boxes"; the C34-XYY, ERS TV display checkout set - which will verify TV display resolution and sensitivity, and system alignment and drift meter function; the C34-ZYY, ERS TV display BME - to provide bench check capability of the TV display "black boxes", C34-ZZZ, ERS flight control system checkout set - to check control reel rates and travel on an end-to-end system basis; C34-ZZY, ERS flight control system BME - to provide a bench check capability for system components.

Existing GSE requiring modification include the following:

a. H14-044, Parachute Handling sling (15%)
b. C14-451, ELS Sequencer control pressure stimuli generator (10%)
c. C14-452, ELS Control electrical test stand (20%)

Technical Documentation

Technical data requirements for the LLS Configuration IV will incorporate four changes (three minor and one major) to the riser retro-system, four changes (all minor) to the ground sensing system, two minor changes to the vision system, and one minor change to the parachute system. All of these changes or modifications will be accomplished at the contractor's facility, except those normally accomplished at the test sites, such as, installation of pyrotechnics and parachutes.

The analysis of technical documentation requirements for Configuration IV LLS items are shown in the LLS Support Requirements Summary Table 6.

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Table 3. LLS Support Requirement Considerations (Configuration I)

LAND LANDING SYSTEM SUPPORT REQUIREMENT CONSIDERATIONS											
CONFIGURATION I											
CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP. HANDLING, ETC)	MAINTAIN-ABILITY
1. ROTATING "FLOWERPOT" (SWIVEL)	N	R	R	R	0	R	R	0	R	R	R
2. WORM DRIVE GEAR BOX	N	R	R	R	0	R	R	0	R	R	R
3. ELECTRIC MOTOR	N	R	R	R	0	R	R	0	R	R	R
4. "FLOWERPOT" SUPPORT STRUCTURE	M	0	0	0	0	0	0	0	0	0	0
5. RELOCATED WIRING TO ERS CABLE CUTTERS	M	0	0	0	0	0	0	0	0	0	0
6. WIRING FROM BATTERIES TO SWIVEL MOTOR	N	R	0	R	0	R	R	0	0	0	0
7. ELECTRICAL SWITCH (DISP. PANEL)	N	R	R	R	0	R	R	0	0	0	0
8. ELECTRICAL SWITCH (ITEM #7) WIRING CHANGES	M	R	0	R	0	R	R	0	0	0	0
9. REVISE SEQUENCE CONTROLLER	M	R	R	R	0	R	R	0	R	0	0
10. ROCKETS (4) LANDING SYSTEM	N	R	R	R	0	R	R	0	R	R	R
11. ROCKET SUPPORT/MOUNT. STRUCTURE	N	0	0	0	0	0	R	0	0	0	0
12. HEAT SHIELD CHANGES	N	R	R	0	0	R	R	R	R	R	0
13. CARTRIDGE-OPERATED PLUG THRUSTERS	N	R	R	R	0	R	R	0	0	R	0
14. THRUSTER (ITEM #13) STRUCTURE	N	0	0	0	0	0	0	0	0	0	0
15. MECHANICAL PROBE (ALT. SENSING BOOM)	N	R	R	R	0	R	R	0	0	0	R
16. PROBE IMPACT SWITCHES	N	R	R	R	0	R	R	0	0	0	0
17. WIRING CHANGES FOR IMPACT SWITCHES, & AFT EQUIPM COMPT. WIRING HARNESS	M	R	0	R	0	R	R	0	0	0	0
18. ROCKET MOTOR AREA PLUMBING	M	0	0	0	0	0	R	0	0	0	R
19. RELOCATION OF HELIUM TANK, FLOTATION SYS. COMPRESSOR, RCS SWITCHES, WIRING, & PLUMBING	M	R	0	R	0	R	R	0	0	0	R
20. AFT EQUIPM BAY ACCESS DOORS (2)	N	R	R	0	0	R	R	0	0	0	R
21. MODIFICATION TO S/C SEQ. SYS. FOR ROCKET SYS. INITIATION	M	R	R	R	0	R	R	0	0	0	0
22. MIRROR (SMALL) (2)	N	R	R	0	0	R	R	0	0	0	R
23. ELIMINATION OF 175 LB OF STRUCTURE FROM THE AFT HEAT SHIELD	M	0	0	0	0	0	R	0	0	0	0
24. PROBE MOUNTING PROVISIONS	N	0	0	0	0	0	R	0	0	0	0
25. ME 453-0009 INITIATOR (2) (PLUG)	N	R	R	R	0	R	R	0	0	0	0
26. CONFIG. I GSE	M	R	R	R	R	R	R	R	R	R	0

0 = No Support Requirement, R = Requirement Exists

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Table 4. LLS Support Requirement Considerations (Configuration II)

CONFIGURATION II — CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP., HANDLING, ETC)	MAINTAIN-ABILITY
1. ROCKET MOUNTING PROVISIONS	N	O	O	O	O	O	R	O	O	O	O
2. HEAT SHIELD CHANGES, ie, HOLES IN HEAT SHIELD, & ABLATIVE MATERIAL	N	R	R	O	O	R	R	R	R	R	O
3. CARTRIDGE-OPERATED PLUG THRUSTERS (4)	N	R	R	R	O	R	R	O	O	R	O
4. THRUSTER (ITEM 3) STRUCTURE	N	O	O	O	O	O	O	O	O	O	O
5. THRUSTER HONEYCOMB INSERTS	N	O	O	O	O	O	O	O	O	O	O
6. ROCKET AREA WIRING & PLUMBING	M	O	O	O	O	O	R	O	O	O	R
7. WIRING FOR TV, RADAR, INFRA-RED SYS & FOR ROCKET IGNITION	N	R	R	R	O	R	R	O	O	O	O
8. RELOCATION OF HELIUM BOTTLE, OXIDIZER TANK, POTABLE WATER TANK AND FLOTATION SYSTEM COMPRESSOR WITH ASSOC. PLUMBING, WIRING & MOUNTING STRUCTURE	M	O	O	O	O	O	R	O	O	O	R
9. CM STRUCTURE MODIFICATION (FRAME 10 MODIF. - FOUR HONEY-COMB CORES IN TOE MODIFIED TO BECOME FRAMES 4,5,6,7 & 8)	M	O	O	O	O	O	R	O	O	O	O
10. FOUR NEW ACCESS DOORS	N	R	R	O	O	R	R	O	O	O	R
11. ELIMINATION OF 200 LB OF STRUCTURE FROM AFT HEAT SHIELD	M	O	O	O	O	O	R	O	O	O	O
12. MODIF. OF S/C SEQ. SYS. FOR ROCKET SYSTEM	M	R	R	R	O	R	R	O	O	O	O
13. ALTIMETER SENSORS MOUNTING STRUCTURE IN HEAT SHIELD	N	O	O	O	O	O	R	O	O	O	O
14. ADD BOLT-ON PROVISIONS TO SEQUENCE CONTROLLER FOR ELECTRONIC BOX	N	O	O	O	O	R	R	O	O	O	O
15. STRUCTURAL MODIF. TO DISPLAY PANEL FOR INSTALL. OF DOOR & MOUNTING PROV. FOR TV SCREEN BEHIND PANEL	M	O	O	O	O	O	R	O	O	O	O
16. (REF. ITEM 15) ASSOC. CHANGES TO EXISTING SWITCH WIRING	M	O	O	O	O	O	R	O	O	O	O
17. MOUNTING OF TWO SMALL MIRRORS AT SIDE WINDOWS	N	R	R	O	O	R	R	O	O	O	R
18. ADDITION OF PARACHUTE HARNESS ATTACH TO FOUR PYROTECHNIC DISCONNECTS IN GUSSETS	N	O	O	O	O	O	R	O	O	O	O

The table's column group is headed LAND LANDING SYSTEM SUPPORT REQUIREMENT CONSIDERATIONS.

O = No Support Requirement, R = Requirement Exists

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Table 4. LLS Support Requirement Considerations (Configuration II) (Cont)

CONFIGURATION II (CON'T) CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICA-TION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP., HANDLING, ETC)	MAINTAIN-ABILITY
19. RELOCATION OF FLOTATION SYS. BAGS	M	O	O	O	O	R	R	O	O	O	O
20. REVISION OF "FLOWERPOT" AND CABLE CUTTERS	M	R	R	R	O	R	R	O	R	R	O
21. ADDITION OF A NEW MORTAR AND SUPPORT STRUCTURE TO TUNNEL AND PARACHUTE DECK	N	R	R	R	O	R	R	O	O	O	O
22. MODIFY SEQUENCE CONTROLLER	M	R	R	R	O	R	R	O	R	O	O
23. ADDITION OF TWO MOTORIZED WINCHES TO GUSSETS OR DECK OF PARACHUTE COMPART. WITH ASSOC. WIRING TO BATTERY	N	R	R	R	O	R	R	O	R	O	O
24. ADDITION OF SWITCH ON PANEL TO CHANGE FROM RCS MODE TO PARACHUTE CONTROL (OR LLS) MODE WHEN USING HAND CONTROLLER	N	R	R	R	O	R	R	O	O	O	O
25. NEW PARASAIL PARACHUTE	N	R	R	O	O	R	R	R	R	R	O
26. NEW ROCKETS (4)	N	R	R	R	O	R	R	R	R	R	R
27. RADAR ALTIMETER	N	R	R	R	O	R	R	R	R	R	O
28. INFRA-RED ALTIMETER	N	R	R	R	O	R	R	R	R	R	O
29. TV SYS. COMPONENTS SCREEN (8" CATH. RAY TUBE)	N	R	R	R	O	R	R	R	R	R	O
CAMERA	N	R	R	R	O	R	R	R	R	R	O
30. FORWARD VELOCITY SENSOR	N	R	R	R	O	R	R	R	R	R	O
31. RADAR SENSOR	N	R	R	R	O	R	R	R	R	R	O
32. INFRA-RED SENSOR	N	R	R	R	O	R	R	R	R	R	O
33. STEERABLE CHUTE FLAP CONTROL UNIT (2)	N	R	R	R	O	R	R	O	R	O	O
34. BACKUP RINGSAIL PARACHUTE	N	R	R	O	O	R	R	R	R	R	O
35. CONFIG II GSE (NEW)	N	R	R	R	O	R	R	R	R	R	O
36. CONFIG II GSE (MODIF.)	M	R	R	R	R	R	R	R	R	R	O

O = No Support Requirement, R = Requirement Exists

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Table 5. LLS Support Requirement Considerations (Configuration III)

CONFIGURATION III CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP., HANDLING, ETC)	MAINTAIN-ABILITY	
1. NEW CLOVERLEAF PARACHUTE	N	R	R	O	O	R	R	R	R	R	O	
2. ROTATIONAL HAND CONTROLLER WIRING TO PERMIT CLOVERLEAF L/D MODULATION & STEERABILITY	M	R	O	R	O	R	R	O	O	O	O	
3. ROCKET MOUNTING PROVISIONS	N	O	O	O	O	O	R	O	O	O	O	
4. HEAT SHIELD CHANGES, i.e., HOLES IN HEAT SHIELD & ABLATIVE MATERIAL	N	R	R	O	O	R	R	R	R	R	O	
5. CARTRIDGE - OPERATED PLUG THRUSTERS	N	R	R	R	O	R	R	O	O	R	O	
6. THRUSTER (ITEM 5) STRUCTURE	N	O	O	O	O	O	O	O	O	O	O	
7. THRUSTER HONEYCOMB INSERTS	N	O	O	O	O	O	O	O	O	O	O	
8. ROCKET AREA WIRING & PLUMBING	M	O	O	O	O	O	R	O	O	O	R	
9. WIRING FOR TV, RADAR, INFRA-RED SYS & FOR ROCKET IGNITION	N	R	R	R	O	R	R	O	O	O	O	
10. RELOCATION OF HELIUM BOTTLE OXIDIZER TANK POTABLE WATER TANK, AND FLOTATION SYS. COMPRESSOR WITH ASSOC. PLUMBING, WIRING, & MOUNTING STRUCTURE	M	O	O	O	O	O	R	O	O	O	R	
11. CM STRUCTURE MODIFICATION (FRAME 10 MODIF. - FOUR HONEY-COMB CORES IN TOE MODIFIED TO BECOME FRAMES 4,5,6,7, & 8)	M	O	O	O	O	O	R	O	O	O	O	
12. FOUR NEW ACCESS DOORS	N	R	R	O	O	R	R	O	O	O	R	
13. ELIMINATION OF 200 LB. OF AFT HEAT SHIELD STRUCTURE	M	O	O	O	O	O	R	O	O	O	O	
14. MODIF. OF S/C SEQ. SYS. FOR ROCKET SYSTEM	M	R	R	R	O	R	R	O	O	O	O	
15. ALTIMETER SENSOR MOUNTING STRUCTURE IN HEAT SHIELD	N	O	O	O	O	O	R	O	O	O	O	
16. ADD BOLT-ON PROVISIONS TO SEQUENCE CONTROLLER FOR ELECTRONIC BOX	N	O	O	O	O	R	R	O	O	O	O	
17. STRUCTURAL MODIF. TO DISPLAY PANEL FOR INSTALL. OF DOOR & MOUNTING PROV. FOR TV SCREEN BEHIND PANEL	M	O	O	O	O	O	R	O	O	O	O	

O = No Support Requirement, R = Requirement Exists

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Table 5. LLS Support Requirement Considerations (Configuration III) (Cont)

LAND LANDING SYSTEM SUPPORT PREQUIREMENT CONSIDERATIONS												
CONFIGURATION III (CONT'D) CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP., HANDLING, ETC)	MAINTAIN-ABILITY	
18. (REF. ITEM 17) ASSOCIATED CHANGES TO EXISTING SWITCH WIRING	M	0	0	0	0	0	R	0	0	0	0	
19. MOUNTING OF TWO SMALL MIRRORS AT SIDE WINDOWS	N	R	R	0	0	R	R	0	0	0	R	
20. ADDITION OF PARACHUTE HARNESS ATTACHED TO FOUR PYROTECHNIC DISCONNECTS IN GUSSETS	N	0	0	0	0	0	R	0	0	0	0	
21. RELOCATION OF FLOTATION SYS. BAGS	M	0	0	0	0	R	R	0	0	0	0	
22. REVISION OF "FLOWERPOT" AND CABLE CUTTERS	M	R	R	R	0	R	R	0	R	R	0	
23. ADDITION OF A NEW MORTAR AND SUPPORT STRUCTURE TO TUNNEL & PARACHUTE DECK	N	0	R	R	R	0	R	R	0	0	0	
24. MODIFY SEQUENCE CONTROLLER	M	R	R	R	0	R	R	0	R	0	0	
25. ADDITION OF TWO MOTORIZED WINCHES TO GUSSETS OR DECK OF PARACHUTE COMPARTMENT WITH ASSOCIATE WIRING TO BATTERY	N	R	R	R	0	R	R	0	R	0	0	
26. ADDITION OF SWITCH ON PANEL TO CHANGE FROM RCS MODE TO PARACHUTE CONTROL (OR LLS) MODE WHEN USING HAND CONTROLLER	N	R	R	R	0	R	R	0	0	0	0	
27. NEW ROCKETS (4)	N	R	R	R	0	R	R	R	R	R	R	
28. NEW RADAR ALTIMETER	N	R	R	R	0	R	R	R	R	R	0	
29. NEW INFRA-RED ALTIMETER	N	R	R	R	0	R	R	R	R	R	0	
30. TV SYSTEM COMPONENTS:												
SCREEN (8" CATH. RAY TUBE)	N	R	R	R	0	R	R	R	R	R	0	
CAMERA	N	R	R	R	0	R	R	R	R	R	0	
31. FORWARD VELOCITY SENSOR	N	R	R	R	0	R	R	R	R	R	0	
32. RADAR SENSOR	N	R	R	R	0	R	R	R	R	R	0	
33. INFRA-RED SENSOR	N	R	R	R	0	R	R	R	R	R	0	
34. STEERABLE CHUTE FLAP CONTROL UNIT (2)	N	R	R	R	0	R	R	0	R	0	0	
35. BACKUP RINGSAIL CHUTE	N	R	R	0	0	R	R	R	R	R	0	
36. CONFIG. III GSE (NEW)	N	R	R	R	0	R	R	R	R	R	0	
37. CONFIG. III GSE (MODIFIED)	M	R	R	R	R	R	R	R	R	R	0	

0 = No Support Requirement, R = Requirement Exists

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Table 6. LLS Support Requirement Considerations (Configuration IV)

CONFIGURATION IV — CHANGE TO APOLLO BLOCK II	NEW (N) or MOD (M)	MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLING	SUPPORT (TRANSP., HANDLING, ETC)	MAINTAIN-ABILITY	
1. ONE RETRO-ROCKET SYSTEM	N	R	R	R	O	R	R	R	R	R	R	
2. ROCKET MOUNTING CRADLE ON PARACHUTE DECK	N	O	O	O	O	O	R	O	O	O	O	
3. HARNESS LINES FOR ROCKET SUSPENSION	N	O	R	O	O	O	R	O	O	O	O	
4. WIRING ADDITION FOR ROCKET IGNITION	N	O	O	O	O	R	R	O	O	O	O	
5. RELOCATION OF DROGUE MORTAR TO -Y BAY	M	O	O	O	O	O	R	O	O	O	R	
6. BEEF-UP OF STRUCTURE AROUND ACCESS PANEL	M	O	O	O	O	O	O	O	O	O	O	
7. NEW HINGE ACCESS PANEL	N	R	R	O	O	O	R	O	O	O	R	
8. ADDITION OF SUPPORT STRUC. TO INNER MOLD LINE OF ACCESS PANEL FOR MOUNTING SENSORS	N	O	O	O	O	O	R	O	O	O	O	
9. ADDITION OF SILICONE RUBBER STRIP IMBEDDED IN ABLATIVE MATERIAL AROUND PERIPHERY PANEL	N	O	O	O	O	O	R	O	O	O	O	
10. MOUNTING STRUCTURE FOR TV CAMERA	N	O	O	O	O	O	R	O	O	O	O	
11. MOUNTING OF TWO SMALL MIRRORS AT SIDE WINDOWS	N	R	R	O	O	R	R	O	O	O	R	
12. ADDITION OF SWITCH ON PANEL TO CHANGE FROM RCS MODE TO PARACHUTE CONTROL WHEN USING HAND CONTROLLER	N	R	R	R	O	R	R	O	O	O	O	
13. ADDITION OF PARACHUTE HARNESS ATTACHED TO FOUR PYROTECHNIC DISCONNECTS IN GUSSETS	N	O	O	O	O	O	R	O	O	O	O	
14. RELOCATION OF FLOTATION SYSTEM BAGS	M	O	O	O	O	R	R	O	O	O	O	
15. REVISION OF "FLOWER POT" AND CABLE CUTTERS	M	R	R	R	O	R	R	O	R	R	O	
16. ADDITION OF A NEW MORTAR AND SUPPORT STRUCTURE TO TUNNEL AND PARACHUTE DECK	N	R	R	R	O	R	R	O	O	O	O	
17. MODIFIED SEQUENCE CONTROLLER	M	R	R	R	O	R	R	O	R	O	O	

LAND LANDING SYSTEM SUPPORT REQUIREMENT CONSIDERATIONS

O = No Support Requirement, R = Requirement Exists

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Table 6. LLS Support Requirement Considerations (Configuration IV) (Cont)

CONFIGURATION IV (CONT'D) CHANGE TO APOLLO BLOCK II		MAINTENANCE	SPARES	CHECKOUT	MODIFICATION	TRAINING	TECHNICAL DOCUMENTATION	SITE ACTIVATION	GSE & SPEC. TOOLS	SUPPORT (TRANSP. HANDLING, ETC)	MAINTAIN-ABILITY	
18. ADDITION OF TWO MOTORIZED WINCHES TO GUSSETS OF PARACHUTE COMPARTMENT WITH ASSOCIATED WIRING TO BATTERIES	M	R	R	R	O	R	R	O	R	O	O	
19. NEW CLOVERLEAF PARACHUTE	N	R	R	O	O	R	R	R	R	R	O	
20. RADAR ALTIMETER	N	R	R	R	O	R	R	R	R	R	O	
21. INFRA-RED ALTIMETER	N	R	R	R	O	R	R	R	R	R	O	
22. RADAR SENSOR	N	R	R	R	O	R	R	R	R	R	O	
23. INFRA-RED SENSOR	N	R	R	R	O	R	R	R	R	R	O	
24. TV SYSTEM COMPONENTS												
SCREEN (8" CATHODE RAY TUBE)	N	R	R	R	O	R	R	R	R	R	O	
TV CAMERA	N	R	R	R	O	R	R	R	R	R	O	
25. HINGE DOOR EJECTION THRUSTER	N	R	R	R	O	R	R	O	O	R	O	
26. STEERABLE CHUTE FLAP CONTROL UNIT (2)	N	R	R	R	O	R	R	O	R	O	O	
27. BACKUP RINGSAIL PARACHUTE	N	R	R	O	O	R	R	R	R	R	O	
28. LANDING DISPLAY DOOR	N	R	R	O	O	R	R	O	O	O	R	
29. CONFIG. IV GSE (NEW)	N	R	R	R	O	R	R	R	R	R	O	
30. CONFIG. IV GSE (MODIF.)	M	R	R	R	R	R	R	R	R	R	O	

O = No Support Requirement, R = Requirement Exists

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FACILITIES

This analysis encompasses the facilities required for the development, design, fabrication and checkout of the land-landing system and its incorporation into the AES vehicles. Facilities requirements, described herein, include land, buildings, building modification, rearrangements, utilities, test equipment (TE), machinery and equipment, manufacturing aids, material handling, parts protection, leases, rentals, office furniture and equipment, and installation of GSE and system measuring devices (SMD). Ground rules of the study are as follows:

1. The AES Facility Plan (Preliminary), SID 65-1147, provided a baseline for the Land-Landing System facilities requirements.

2. Existing facilities at Downey, KSC, and El Centro will be utilized to the maximum extent.

3. No Command Module or Land-Landing System functions will be required at S&ID, Tulsa.

4. The facilities analyses for KSC will be provided by Test and Operations and Logistics.

5. The Boilerplate Aerial Drop Tests are to be conducted at the El Centro facilities utilizing a command module boilerplate vehicle. It is assumed that the complete testing of any one of four separate and distinct land-landing configurations might be conducted at El Centro.

6. It is assumed that facilities, as required, can be made available at Downey and El Centro for the Land-Landing System in performance of interface compatibility tests, boilerplate tower drop tests, and boilerplate aerial drop tests.

7. Qualification test of the rockets, modified Gemini or new rockets, will be completed at the subcontractor's site.

ENGINEERING DEVELOPMENT LABORATORY

Engineering Development Laboratory (EDL) research and development supports S&ID's major programs activities. The Downey facilities utilized by EDL are depicted in Figure 32. Major technological advances are continually being made in materials development. New manufacturing fabrication and processing methods are constantly being devised as a result of putting concepts into practice. Environmental test techniques realistically simulate pressure, cryogenic and pyrogenic temperatures, and other severe conditions of space related to spacecraft development.

Development and Qualification Testing

Land-Landing System, parts, components and subsystems will be tested to evaluate materials and components and insure that all hardware meets design and performance requirements. Existing EDL testing facilities, which include vibration, shock, acoustics, structural, thermal, space simulation and pneumatics, will be capable of handling land-landing system testing requirements. EDL facilities requirements identified during the PDP are negligible. Further analysis during the FDP will be required.

Impact Test Facility

The impact test tower facility is used for drop tests of the command module for evaluation of impact and of crew support system. Drops onto land or water are made with various attitudes of pitch, yaw, and roll and with varying vertical and horizontal velocities. The test tower in operation is shown in Figure 33. This facility is to be utilized for the land-landing system testing.

Tower dimensions are pendulum suspension height of 125 feet and base of 80 by 60 feet. The water drop area is 120 feet square by 20 feet deep and the earth drop area is 130 by 60 feet.

Due to the use of live retro rockets in the drop tests, potential hazards and possible damage to the drop area from rocket force is foreseen if the test area is used in its present configuration. To eliminate these conditions a modification to the drop area is required. A wider and deeper water impact area is necessary and an increase in the drop height for land drops will also be required. The latter will be accomplished by lowering the ground level in the impact area.

FABRICATION AND ASSEMBLY, DOWNEY

Structural fabrication and assembly of the CSM is accomplished in 110,000 square feet of manufacturing area in Building 1. This area contains overhead handling systems, welding systems and equipment to perform cutting, shaping and forming of metal subassemblies. Sheet metal fabrication, machine

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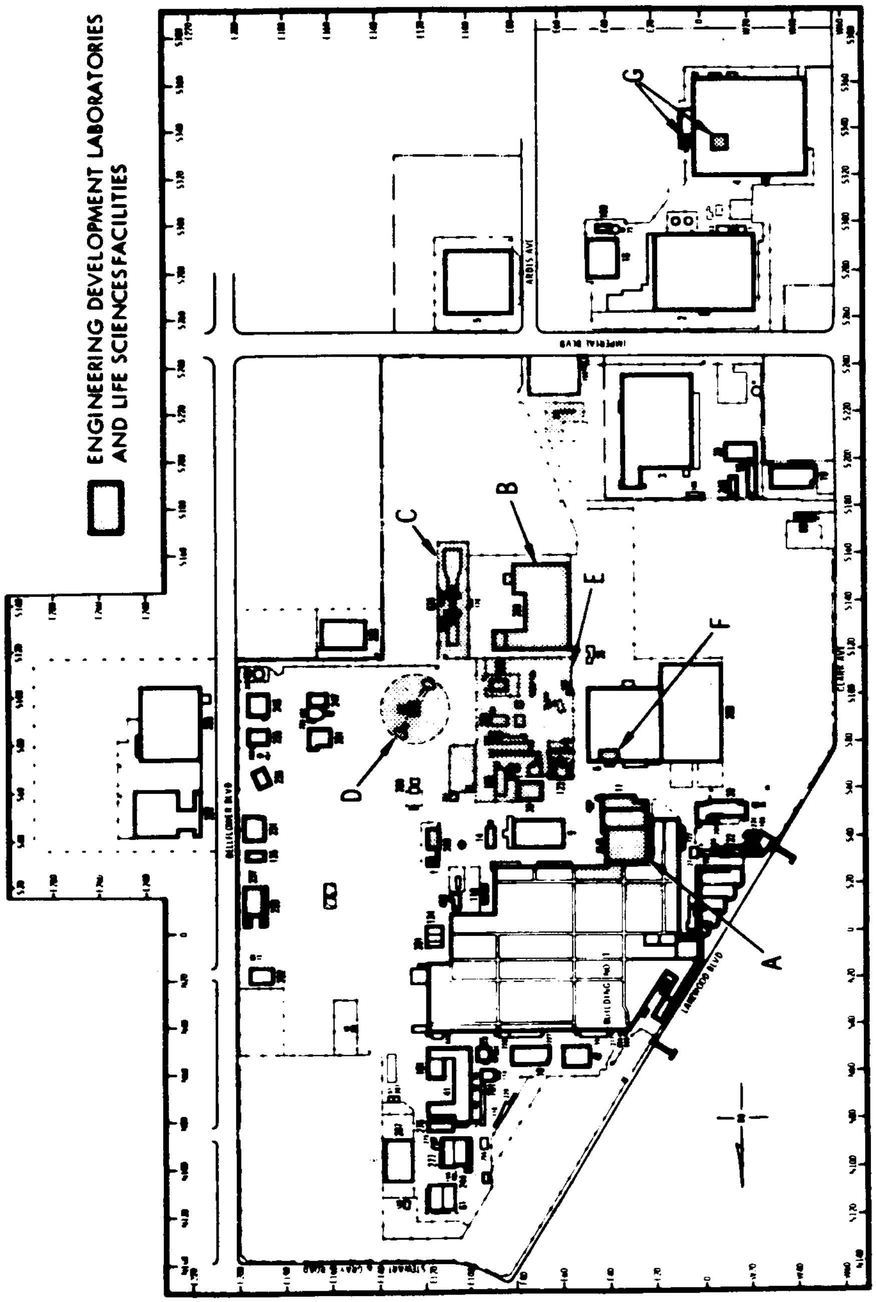

A. EDL, GENERAL LABORATORIES
B. BUILDING 288, SPACE SYSTEMS DEVELOPMENT FACILITY
C. IMPACT TEST FACILITY
D. ROTATIONAL RESEARCH FACILITY
E. HAZARDOUS TEST AREA
F. APOLLO TELECOMMUNICATIONS
G. APOLLO LIGHTING LAB

Figure 32. Engineering Development Laboratories Facilities

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Figure 33. Downey Impact Test Tower

shop and tooling areas in support of fabrication and assembly are also located in this area.

An additional area of 14,700 square feet, adjacent to the fabrication and assembly area, is used to provide tubing mock-ups, templates and wire harness mock-ups. Modified and/or new tooling will be located in the existing manufacturing area with no additional area requirement. Existing material handling consisting of slings, dollies and racks, will, in general, be compatible with the new land-landing system. Further analysis of material handling requirements will be required during the Final Definition Phase.

INSTALLATION, TEST AND CHECKOUT, BUILDING 290, DOWNEY

Command and Service Module systems installation and the checkout of the CSM are conducted in a specialized facility. This dust controlled building consists of low bay area of 50 by 410 by 40 feet high and a high bay area of 63 by 410 by 60 feet high. The operations performed are final assembly effort relating to the installation of components, subsystems and systems, electrical and functional check of all systems, CSM combined and integrated checkout, heat shield installation, cleaning and preparation for shipment.

Installation of systems components will not require any additional material handling equipment. Access to the vehicle will be provided by existing work platforms and dollies. The existing heat shield installation tools will be used to install the heat shield used with the land-landing system. Material handling used in support of this operation will remain unchanged.

The checkout operations performed in the integrated checkout stations in Building 290 (Figure 34) will require modification to some GSE items. Existing locations and power requirements of affected GSE will remain unchanged. No significant impact has been identified in the preliminary definition, but further analysis in the Final Definition Phase will be required.

In the bench maintenance area in Building 290 all pre-installation checkout operations, malfunction isolation of systems and subsystems, and repairs of a minor nature are performed. Modifications to some BME are required to perform required tests on the land-landing system. Minimum impact to facilities is required to support this change.

SUPPORTING FUNCTIONS

Supporting functions include Engineering, Test and Quality Assurance, Site Activation and Logistics, Facilities and Industrial Engineering. Facilities for these functions consist of office area and equipment, special and general purpose laboratories and equipment for research, development and testing in all areas of the physical and applied sciences. Continuous effort is expended in utilizing these facilities to create better production methods, better quality and higher reliability and advancement of the state-of-the-art in the total scope of spacecraft development. Facilities requirements identified for the supporting functions during the PDP are negligible.

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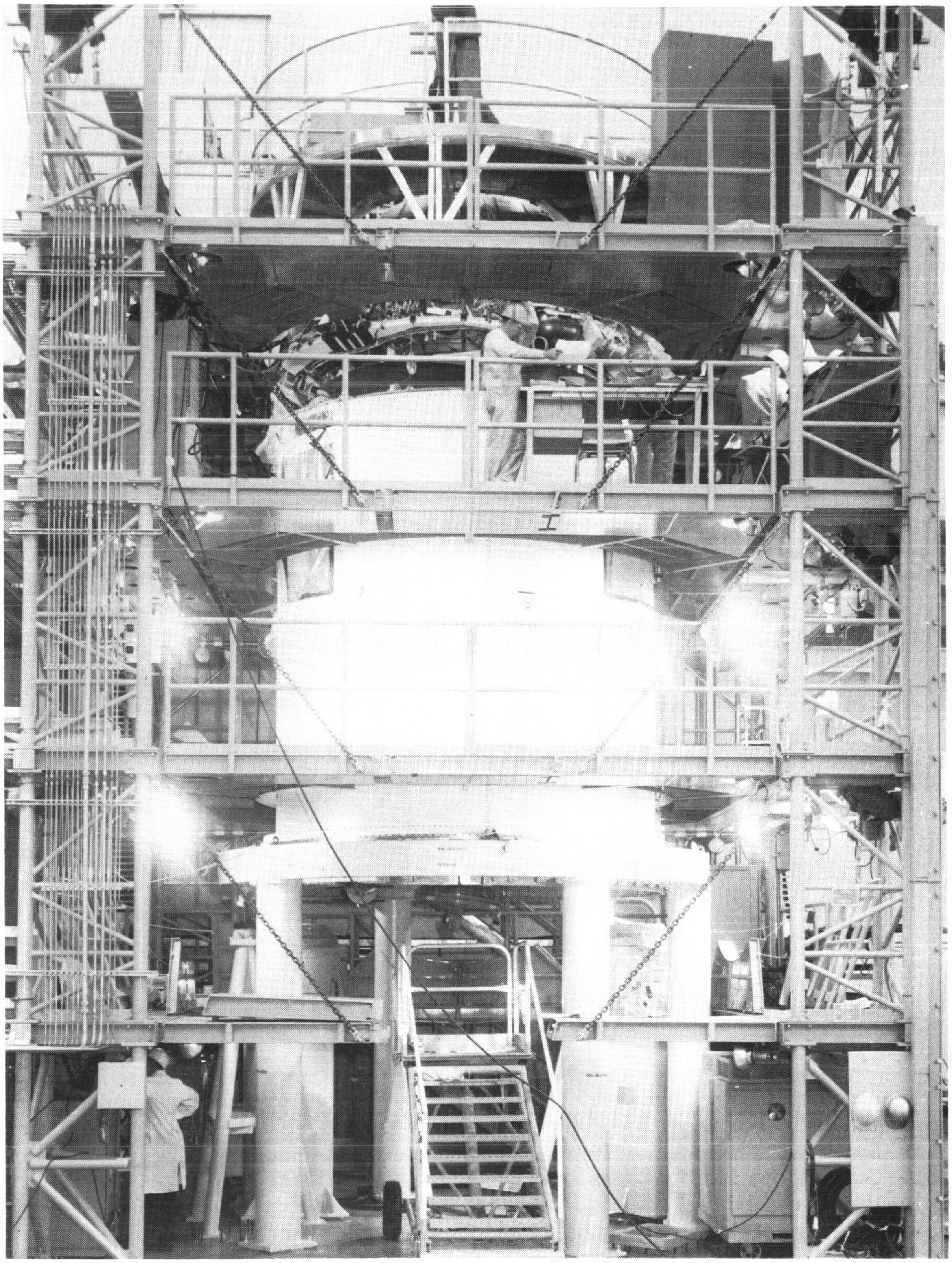

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Figure 34. Integrated Check-out Station, Bldg 290

EL CENTRO, CALIFORNIA

The Naval Air Facility at El Centro, California, Figure 35, contains an aerial drop-test range that is two miles in diameter, level, clear of obstructions, accessible to recovery vehicles and at/or near sea level. Facilities include a rigging area, packing tables, parachute drying, fabric repair, support equipment, support aircraft and recovery vehicles.

The Land-Landing Boilerplate Aerial Drop Tests are to be conducted at this facility utilizing a C/M boilerplate vehicle complete with the entire land-landing system including parachute system, landing rocket system and control system. No additional facilities requirements have been identified for this site during the preliminary definition. Further analysis will be required during the Final Definition Phase.

The buildings and facilities to be utilized for the land-landing system testing at El Centro are as follows:

1. Administrative and Parachute Storage, Building 231. This building will be used for office area and for storage of parachutes.

2. Parachute Packing, Building 289. This building will be used to pack parachutes for the AES Land-Landing System.

3. Apollo Operations, Building 225. This building can be used as work area for repair of electronic components, machine shop, tool crib, and storage.

4. Pyrotechnic Storage, Building 224. This building will be used to provide safe storage for pyrotechnics.

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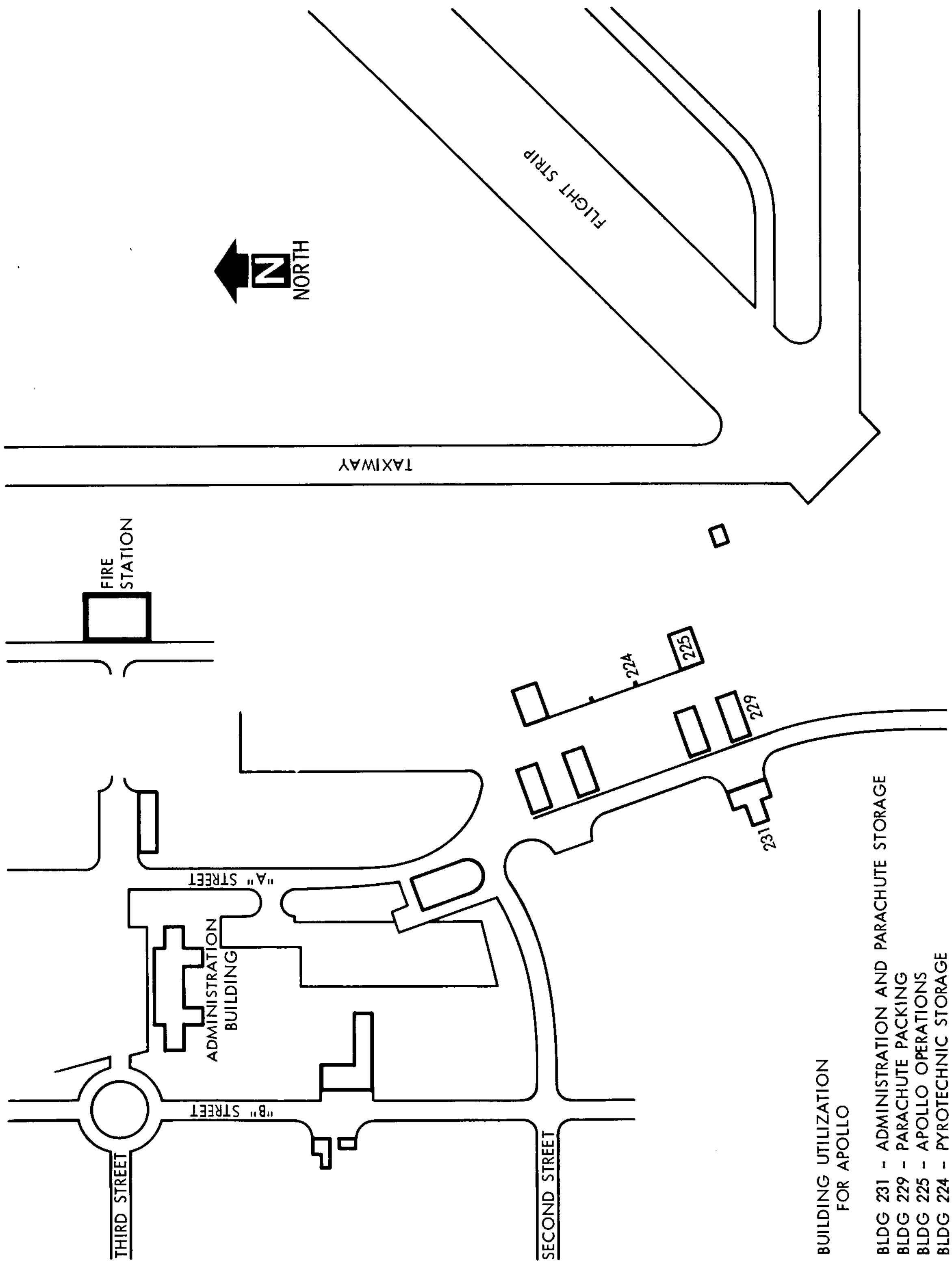

BUILDING UTILIZATION FOR APOLLO

BLDG 231 - ADMINISTRATION AND PARACHUTE STORAGE
BLDG 229 - PARACHUTE PACKING
BLDG 225 - APOLLO OPERATIONS
BLDG 224 - PYROTECHNIC STORAGE

Figure 35. Apollo - El Centro Test Facility

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PROGRAM SCHEDULES

MASTER DEVELOPMENT SCHEDULE

The Development/Operations Phase Master Development Schedule 11-2 (Figure 36) portrays turnaround time, processing time, and in-work spans for assembly, subsystem installation, mission readiness checkout operations, and field pre-launch operations for each spacecraft. In addition, booster launch dates are shown for reference purposes. The rationale of the Master Development Schedule reflects the basic policy of the AES program, which states that maximum use be made of Apollo hardware and technology in the development of the extended-mission capability spacecraft on a non-interference basis with the Apollo program.

LAND-LANDING SYSTEM MASTER SCHEDULE

In the development of an Integrated Land-Landing Master Schedule for the four LLS configurations, the stated baselines and guidelines were applied.

The Land-Landing Master Schedule (Figure 37) is subdivided into three sections:

1. Major Milestones - Design and Development

2. Support Milestones - Design and Development

3. Manufacturing, Test, and Field Operations Schedules

Each of the sections covers the four basic Land-Landing System configurations in summary format. Detail schedules for these four configurations are provided separately under the documents headed Land-Landing Study Integrated Schedules I-IA, I-IB, I-IC, I-ID, identified as Figures 7, 8, 9, and 10, respectively.

In establishing the milestones listed in the first two sections of the Master Schedule, all major development and support requirements were identified and evaluated for logical sequencing. Appropriate time intervals for individual tasks were then established to assure accurate time phasing between events. Summarily, the major milestones for design and development for the Land-Landing Design and Development Program are as follows:

(a) <u>Design Release</u> - The 100% design release points are significant milestones in that all engineering design data is made available for Manufacturing to implement and initiate total fabrication requirements in support of individual boilerplate of spacecraft. Prior to the establishment of these 100% design release points, a thorough evaluation was made to ensure that sufficient

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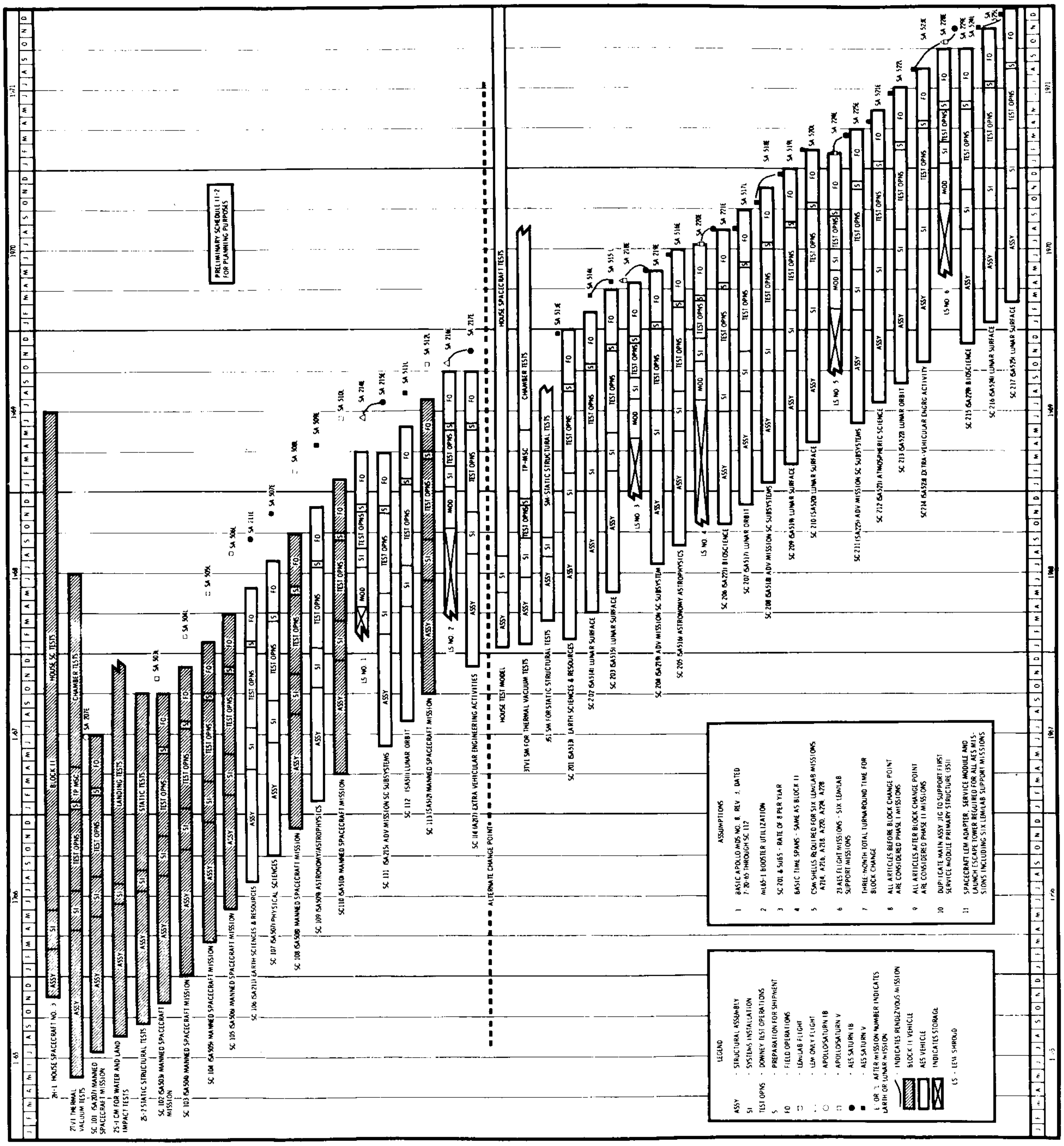

Figure 36. AES Development Operations Phase Master Development Schedule 11-2

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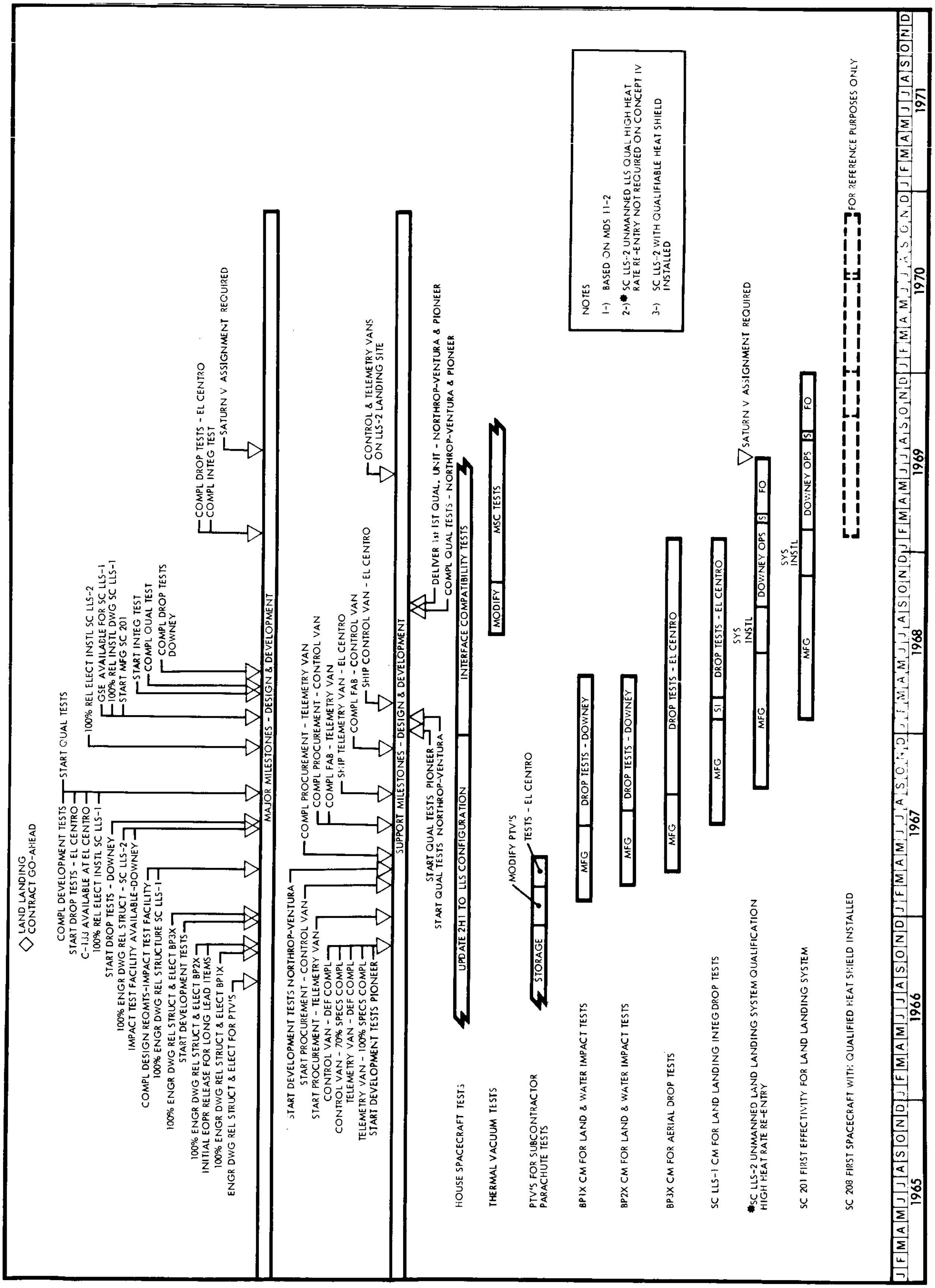

Figure 37. Land Landing System Master Schedule

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design lead time was available. These 100% design release points also establish the basis for identification of GSE design and configuration; and subsequently checkout procedures. It is to be noted, however, that 100% design release excludes changes.

(b) EOPR Release - Initial EOPR release for long-lead items identifies subcontractor engineering release requirements in support of Land-Landing delta changes. Subcontractor interface requirements are established early and long-lead item constraints identified for management action and visibility. Past experience has shown that subcontractor requirements often prove to be the pacing factor for NAA planning.

(c) Facilities - Minimal changes to available facilities are required to support the Land-Landing requirements. The only significant modification will be the requirement for widening and deepening the water pool at the Impact Test facility.

(d) Test - The test schedules and milestones provided the required visibility to measure progress and ensure successful accomplishment of the drop test. Detail test data in support of the listed milestones may be found in the schedules shown under Figures 7, 8, 9, and 10.

(e) Support Milestones - These milestones are based on subcontractor planning documents, and on the long lead time requirements for the Telemeter and Control Tracking Van equipment in support of the parachute system.

The third portion of the Master Schedule covers the Development Test Plan and identifies the tests to be performed, test articles, test facilities, and test schedules for the four baseline configurations. The test plan also incorporates the development, pre-qualification, and qualification phases. Prime emphasis was placed on this portion of the schedule in identifying all major test activities and for providing for a logical sequencing of these activities in line with program requirements. Manufacturing will provide boilerplate articles for the initial drop tests. Two additional spacecraft structures will also be provided to accommodate spacecraft verification tests. This will be done with the understanding that there will be minimum interference with Apollo Block II requirements. It should be noted that for Concepts I, II, and III, a Saturn V booster must be made available to accommodate the unmanned flight of Spacecraft LLS-2.

[redacted]

The Land-Landing Integrated Master Schedule reflects timing and phasing that is considered reasonable and realistic for development of a Land-Landing System capable of operational flight on the First AES Flight (SC 201). Phasing of the major elements of Design, Development, Fabrication, and Test have been thoroughly analyzed and technically assessed to provide an optimum development program for the Land-Landing capability.

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